THE

OPERATIVE MECHANIC,

AND

BRITISH MACHINIST;

BEING

A PRACTICAL DISPLAY

OF

THE MANUFACTORIES AND MECHANICAL ARTS
OF THE UNITED KINGDOM.

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THE OPERATIVE MECHANIC AND MACHINIST.

SAW-MILLS.

Saw-mills, constructed for the purpose of sawing either timber or stone, are moved by animals, by water, by wind, or by steam. They may be distinguished into two kinds; those in which the motion of the saw is reciprocating, and those in which the saws have a rotatory motion. In either case the researches of theorists have not yet turned to any account: instead therefore of giving any uncertain theory here, we shall proceed to the descriptive part, and refer those who wish to see some curious investigations on this subject to a Memoir on the Action of Saws, by Euler, en Mem. Acad. Roy. Berlin, 1756.

Reciprocating saw-mills, for cutting timber, and moved by water, do not exhibit much variety in their construction. The saw-mill represented in fig. 450, is taken from Gray's Experienced Mill-wright; but it only differs in a few trifling particulars, from some which are described in *Belidor's Architecture Hydraulique*, and in Gallon's Collection of Machines approved by the French Academy.

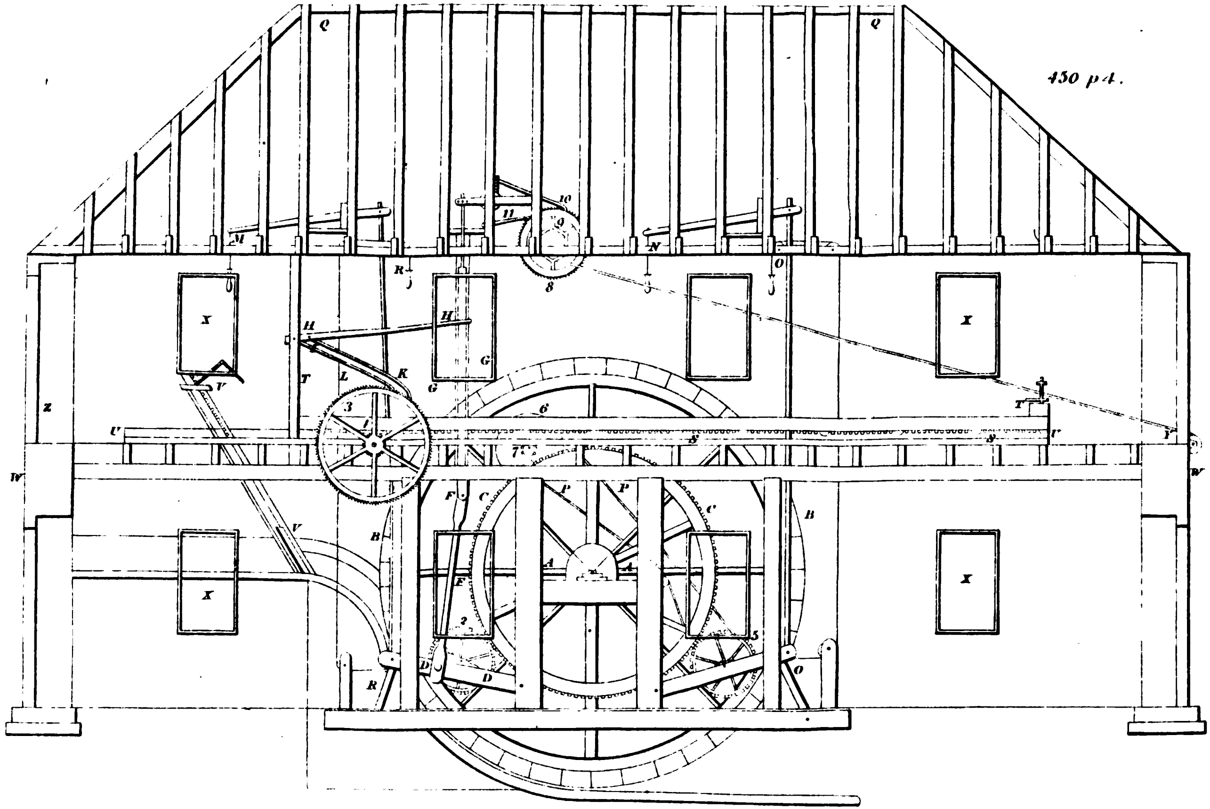
The plate just referred to shows the elevation of the mill. A A the shaft or axle upon which is fixed the wheel B B, (of 17½ or 18 feet diameter,) containing 40 buckets to receive the water which impels it round C C, a wheel upon the same shaft containing 96 teeth, to drive the pinion No. 2, having 22 teeth, which is fastened upon an iron axle or spindle, having a coupling-box on each end that turns the cranks, as D D, round; one end of the pole E is put on the crank, and its other end moves on a joint or iron bolt at F, in the lower end of the frame G G. The crank D D, being turned round in the pole E, moves the frame G G up and down, and those having saws in them, by this motion cut the wood. The pinion No. 2, may work two, three, or more cranks, and thus move as many frames or saws. No. 3, an iron wheel having angular teeth, which one end of the iron K takes hold

of, while its other end rolls on a bolt in the lever H H. One end of this lever moves on a bolt at I, the other end may lay in a notch in the frame G G, so as to be pulled up and down by it. Thus the catch K pulls the wheel round, while the catch I falls into the teeth and prevents it from going backwards.

Upon the axle of No. 3, is also fixed the pinion No. 4, taking into the teeth in the under edge of the iron bar, that is fastened upon the frame T T, on which the wood to be cut is laid: by this means the frame T T is moved on its rollers S S, along the fixed frame U U; and of course the wood fastened upon it is brought forward to the saws as they are moved up and down by reason of the turning of the crank D D. V V the machine and handle to raise the sluice, when the water is to be let upon the wheel B B, to give it motion. By pulling the rope at the longer arm of the lever M, the pinion No. 2, is put into the hold or gripe of the wheel C C, which drives it; and by pulling the rope R, this pinion is cleared from the wheel. No. 5, a pinion containing 24 teeth, driven by the wheel C C, and having upon its axle a sheave, on which is the rope P P, passing to the sheave No. 6, to turn it round; and upon its axle is fixed the pinion No. 7, acting on the teeth in an iron bar upon the frame T T, to roll that frame backwards when empty. By pulling the rope at the longer arm of the lever N, the pinion No. 5, is put into the hold of the wheel C C; and by pulling the rope O, it is taken off the hold. No. 8, a wheel fixed upon the axle No. 9, having upon its periphery angular teeth, into which the catch No. 10 takes, and being moved by the lever attached to the upper part of the frame G, it pushes the wheel No. 8 round; and the catch, No. 11, falls into the teeth of the wheel, to prevent it from going backward, while the rope rolls in its axle, and drags the logs or pieces of wood in at the door Y, to be laid upon the movable frames T T, and carried forward to the saws to be cut. The catches Nos. 10 and 11 are easily thrown out of play when they are not wanted. The gudgeons in the shafts, rounds of the cranks, spindles, and pivots, should all turn round in cods or bushes of brass. Z, a door in one end of the mill-house, at which the wood is conveyed out when cut. W W, walls of the mill-house. Q Q, the couples or framing of the roof. X X X, &c. windows to admit light to the house.

Saw-mills for cutting blocks of stone are generally, though not always, moved horizontally; the horizontal alternate motion may be communicated to one or more saws, by means of a rotatory motion, either by the use of cranks, &c. or in some such way as the following. Let the horizontal wheel A B D C, fig. 451, drive the pinion O N, this latter carrying a vertical pin P, at the distance of about one-third of the diameter from the centre. This pinion and pin are represented separately in No. 2 of fig. 451. Let the frame W S T V, carrying four saws, marked 1, 2, 3, 4, have wheels, V, T, W, W, each running in a groove or reel, whose direction is parallel to the proposed direction of the saws: and let a transverse groove P R, whose length is double the distance of the pin P from the centre of the pinion, be cut in the saw-frame to receive that pin. Then, as the great wheel revolves, it drives the pinion, and carries round the pin P; and this pin being compelled to slide in the straight groove P R, while by the rotation of the pinion on which it is fixed, its distance from the great wheel is constantly varying, it causes the whole saw-frame to approach and recede from the great wheel alternately, while the grooves in which the wheels run confine the frame, so as to move in the direction T *t*, V *v*. Other blocks may be sawn at the same time by the motion of the great wheel, if other pinions and frames running off in the directions of the respective radii, E B, E A, E C, be worked by the teeth at the quadrantal points B A and C. And the contrary efforts of these four frames and pinions, will tend to soften down the jolts, and equalize the whole motion.

450 p 4.



SAW MILL

The same contrivance, of a pin fixed at a suitable distance from the centre of a wheel, and sliding in a groove, may serve to convert a reciprocating into a rotatory motion; but it will not be preferable to the common conversion by means of a crank.

When saws are used to cut blocks of stone into pieces having cylindrical surfaces, a small addition is made to the apparatus. See figs. 452 and 453. The saw, instead of being allowed to fall in a vertical groove, as it cuts the block, is attached to a lever or beam F G, sufficiently strong; this lever has several holes pierced through it, and so has the vertical piece E D, which is likewise movable towards either side of the frame in grooves in the top and bottom pieces A L, D M. Thus the length K G of the radius can be varied at pleasure, to suit the curvature N O; and as the saw is moved backwards and forwards by proper machinery, in the direction C B, B C, it works lower and lower into the block, while, being confined by the beam F G, it cuts the cylindrical portion from the block P, as required.

When a complete cylindrical pillar is to be cut out of one block of stone, the first thing will be to ascertain in the block the position of the axis of the cylinder; then lay the block so that such axis shall be parallel to the horizon, and let a cylindrical hole of from one to three inches diameter be bored entirely through it. Let an iron-bar, whose diameter is rather less than that of the tube, be put through it, having just room to slide freely to and fro as occasion may require. Each end of this bar should terminate in a screw, on which a nut and frame may be fastened; the nut-frame should carry three flat pieces of wood or iron, each having a slit running along its middle nearly from one end to the other, and a screw and handle must be adapted to each slit: by these means the frame work at each end of the bars may readily be so adjusted as to form isosceles or equilateral triangles: the iron-bar will connect two corresponding angles of these triangles; the saw to be used, two other corresponding angles; and another box of iron or of wood, the two remaining angles; to give sufficient strength to the whole frame. This construction, it is obvious, will enable the workman to place the saw at any proposed distance from the hole drilled through the middle of the block; and then, by giving the alternating motion to the saw-frame, the cylinder may at length be cut from the block as required. This method was first described in the Collection of Machines approved by the Paris Academy.

If it were proposed to saw a conic frustrum from such a block, then let two frames of wood or iron be fixed to those parallel ends of the block which are intended to coincide with the bases of the frustrum, circular grooves being previously cut in these frames to correspond with the circumferences of the two ends of the proposed frustrum; the saw being work-

ed in these grooves, will manifestly cut the conic surface from the block. This, we believe, is the contrivance of Sir George Wright.

The best method of drilling the hole through the middle of the proposed cylinder seems to be this: on a carriage running upon four low wheels let two vertical pieces, (each having a hole just large enough to admit the borer to play freely,) be fixed, two or three feet asunder, and so contrived that the pieces and holes to receive the borer may, by screws, &c. be raised or lowered at pleasure, while the borer is prevented from sliding backwards and forwards by pieces upon its bar, which are larger than the holes in the vertical pieces, and which, as the borer revolves, press against these pieces: let a part of the boring bar between the two vertical pieces be square, and a grooved wheel with a square hole of a suitable size be placed upon this part of the bar; then the rotatory motion may be given to this bar by an endless-band, which shall pass over this grooved wheel and a wheel of much larger diameter in the same plane, the latter wheel being turned by a winch-handle in the usual way. As the boring proceeds, the carriage with the borer may be brought nearer and nearer the block, by levers and weights.

Circular saws, acting not by a reciprocating, but by a rotatory motion, have been long known in Holland, where they are used for cutting wood used for veneering. They were introduced into this country, we believe, by General Bentham, and are now used in the dock-yard at Portsmouth, and in a few other places; but they are not as yet so generally adopted as might be wished, considering how well they are calculated to abridge labour, and to accomplish, with expedition and accuracy, what is very tedious and irksome to perform in the usual way. Circular saws may be made to turn either in horizontal, vertical, or inclined planes; and the timber to be cut may be laid upon the plane in any direction; so that it may be sawed by lines making any angles whatever, or at any proposed distance from each other. When the saw is fixed at a certain angle and at a certain distance from the edge of the frame, all the pieces will be cut of the same size, without marking upon them by a chalked line, merely by causing them to be moved along, and keeping one side in contact with the side of the frame; for then as they are brought one by one to touch the saw revolving on its axle, and are pressed upon it, they are soon cut through.

Mr Smart, of the Ordnance Wharf, Westminster Bridge, has several circular saws, all worked by a horse, in a moderate

sized walk; one of these, intended for cutting and boring tenons, used in this gentleman's hollow masts, is represented in fig. 454.

N O P Q R is a hollow frame, under which is a part of the wheel-work of the horse-mill. A B C D E F are pullies, over which pass straps or bands, the parts of which out of sight run upon the rim of a large vertical wheel; by means of this simple apparatus the saws S S are made to revolve upon their axles, with an equal velocity, the same band passing round the pullies D C, upon those axles; and the rotatory motion is given to the borer G by the band passing over the pulley A. The board I is inclined to the horizon in an angle of about 30 degrees; the plane of the saw S is parallel to that of the board I, and about a quarter of an inch distant from it, while the plane of the saw S 1 is vertical, and its lowest point at the same distance from the board I. Each piece of wood K, out of which the tenon is to be cut, is about four inches long, and an inch and a quarter broad, and ⅝ of an inch thick. One end of such piece is laid so as to slide along the ledge at the lower part of the board I, and as it is pushed on by means of the handle H, it is first cut by the saw S, and immediately after by the saw S 1; after this the other end is put lowest, and the piece is again cut by both saws: then the tenon is applied to the borer G, and as soon as a hole is pierced through it, it is dropped into the box beneath.

By the above process, at least 30 tenons may be completed in a minute, with greater accuracy than a man could make one in a quarter of an hour with the common hand saw and gimlet. Similar contrivances may, by slight alterations, be fitted for many other purposes, particularly all such as may require the speedy sawing of a great number of pieces into exactly the same size and shape. A very great advantage attending this sort of machinery is, that when once the position of the saws and frame is adjusted, a common labourer may perform the business just as well as the best workman.

BARK-MILL.

The bark-mill is constructed for the purpose of grinding and preparing bark till it is fit for the tanner.

Bark-mills, like most other mills, are worked either by means of horses, by water, or by wind.

One of the best mills we have seen described for these purposes is that invented by Mr Bagnall, of Worsley, in Lancashire. This machine will serve not only to chop bark, to grind, to riddle, and pound it; but to beam or work green hides and skins out of the mastering or drench, and make them ready for the ouse or bark-liquor; to beam sheep-skins, and other skins, for the skinner's use; and to scour

and take off the bloom from tanned leather, when in the currying state.

Fig. 455 is a horizontal plan of the mill; fig. 456 a longitudinal section of it; fig. 457 a transverse section of it.

A, the water-wheel, by which the whole machinery is worked.

B, the shafts.

C, the pit-wheel, which is fixed on the water-wheel shaft B, and turns the upright shaft E, by the wheel F, and works the cutters and hammer by tapets.

D, the spur and bevel-wheels at the top of upright shafts.

E, the upright shaft.

F, the crown-wheel, which works in the pit-wheel C.

G, the spur-nut to turn the stones I.

P, the beam, with knives or cutters fixed at the end to chop or cut the bark, which bark is to be put upon the cutters or grating *i*, on which the beam is to fall.

Q, the tryal that receives the bark from the cutters *i*, and conveys it into the hopper H, by which it descends through the shoe J to the stones I, where it is ground.

K, the spout, which receives the bark from the stones, and conveys it into the tryal L; which tryal is wired, to shift or dress the bark as it descends from the stones I.

M, the trough, to receive the bark that passes through the tryal L.

R, the hammer, to crush or bruise the bark that falls into the dish S, which said dish is on the incline, so that the hammer keeps forcing it out of the lower side of the said dish, when bruised.

k, a trough, to receive the dust and moss that passes through the tryal Q.

T, the bevel-wheel that works in the wheel D, which works the beam-knife by a crank V, at the end of the shaft *u*.

W, the penetrating rod, which leads from the crank V to the start *x*.

x, the start, which has several holes in it to lengthen or shorten the stroke of the beam-knife.

y, the shaft, to which the slide-rods *h h* are fixed by the starts *n n*.

h, the slide-rod, on which the knife *f* is fixed, which knife is to work the hides, &c. On the knife are two springs *a a*, to let it have a little play as it makes its strokes backwards and forwards, so that it may not scratch or damage the hides, &c.

z, is a catch in the slide-rod *h*, which catches on the arch-head *e*; and the said arch-head conveys the knife back without touching the hide, and then falls back to receive the catch again.

l, the roller to take up the slide-rod *h*, while the hides are shifting on the beam *b*, by pulling at the handle *m*.

b, the beam to work the hides, &c. on. Each beam has four wheels, *p p*, working in a trough-road, *g g*, and removed by the levers *c c*. When the knife has worked the hides, &c. sufficiently in one part, the beam is then shifted by the lever *c*, as far as is wanted.

d, a press, at the upper end of the beam, to hold the hide fast on the beam while working.

e, an arch-head, on which the slide-rod *h* catches.

f, the knife fixed on the slide-rod *h*, to work the hides, &c.

i, cutters or grating to receive the bark for chopping.

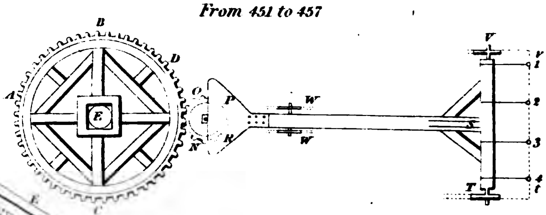
The beam P, with knives or cutters, may either be worked by tapets, as described, or by the bevel-wheel T with a crank, as V, to cut the same as shears.

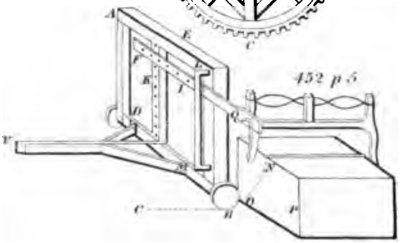
The knife *f* is fixed at the bottom of the start, which is fixed on the slide rod *h*; the bottom of the start is split open to admit the knife, the width of one foot; the knife should have a gudgeon at each end, to fix in the open

451 p 4

From 451 to 457

451 2





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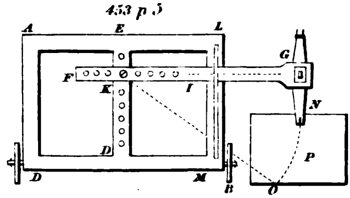

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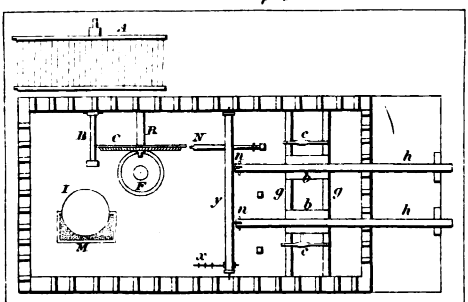

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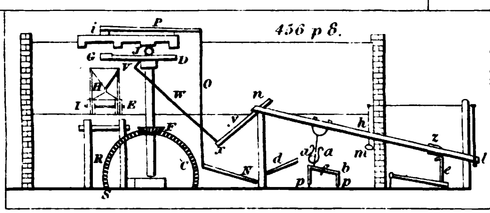

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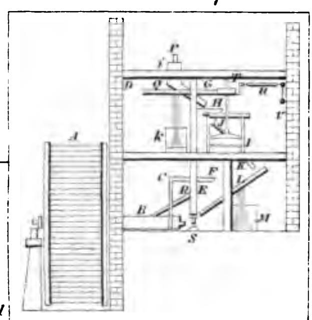

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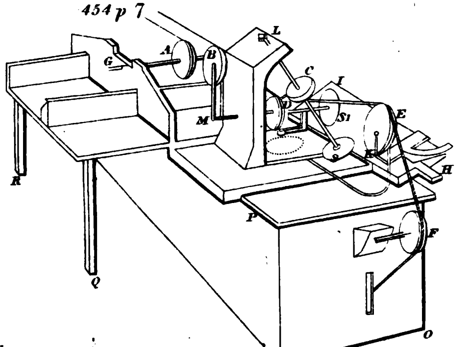


part of the start; and the two springs *a a* prevent the knife from giving too much way when working. The knife should be one foot long, and four or five inches broad.

The arch-head *e* will shift nearer to or further from the beam *h*, and will be fixed so as to carry the knife back as far as is wanted, or it may be taken away till wanted.

The roller *l* is taken up by pulling at the handle *m*, which takes up the slide-rod so high as to give head-room under the beam-knife; the handle may be hung upon a hook for that purpose. The slide-rod will keep running upon the roller all the time the hide is shifting; and when the hide is fixed, the knife is put on the beam again by letting it down by the handle *m*. There may be two or more knives at work on one beam at the same time, by having different slide-rods; there should be two beams, so that the workman could be shifting one hide, &c. while the other was working. The beam must be flat, and a little on the incline; as to the breadth, it does not matter; the broader it is, the less shifting of the hides will be wanted, as the lever *c* will shift them as far as the width of the hide, if required. Mr Bagnall has formed a kind of press *d*, to let down, by a lever, to hold the hide fast on each side of the knife, if required, so that it will suffer the knife to make its back stroke without pulling the hide up as it comes back. The slide-rod may be weighted, to cause the knife to lay stress on the hide, &c. according to the kind and condition of the goods to be worked.

Hides and skins for the skinner's use are worked in the same way as for the tanner's.

Scouring of tanned leather for the currier's use can be done on the beam, the same as working green hides; it is only taking the knife away, and fixing a stone in the same manner as the knife by the said joint, and to have a brush fixed to go either before or after the stone. The leather will be much sooner and better secured this way than by hand.

The whole machinery may be worked by water, wind, steam, or any other power; and that part of the machinery which relates to the beaming part of the hides, may be fixed to any horse bark-mill, or may be worked by a horse or other power separately.

OIL-MILLS.

As these kingdoms do not produce the olive, it would be needless to describe the mills which are employed in the southern parts of Europe; we shall therefore content ourselves with a description of a Dutch oil-mill, employed for grinding and pressing linseed, rapeseed, and other oleaginous grains; and, to accommodate our description still more to our local circumstances, shall employ water as the first mover; thus avoiding the enormous expense and complication of a windmill.

Description of fig. 458.

1 is the elevation of a wheel, over or under-shot, as the situation may require.

2, the bell-metal socket, supported by masonry, for receiving the outer gudgeon of the water-wheel.

3, the watercourse.

Fig. 459.

1, a spur-wheel upon the same axis, having 52 teeth.

2, the trundle that is driven by No. 1, and has 78 staves.

3, the wallower, or axis for raising the pestles. It is furnished round its circumference with wipers for lifting the pestles, so that each may fall twice during one turn of the water wheel: that is, three wipers for each pestle.

4, a frame of timber carrying a concave half cylinder of bell-metal, in which the wallower, (cased in that part with iron plates,) rests and turns round.

5, masonry supporting the inner gudgeon of the water-wheel and the above-mentioned frame.

6, gudgeon of the wallower, which bears against the bell-metal step fixed in the wall. This double support of the wallower is found to be necessary in all mills which drive a number of heavy stampers.

Fig. 460 is the elevation of the pestle and press-frame, their furniture, the mortars, and the press-pestles.

1, the six pestles.

2, cross-pieces between the two rails of the frame, forming, with these rails, guides for the perpendicular motion of the pestles.

3, the two rails; the back one is not seen. They are checked and bolted into the standards, No. 12.

4, the tails of the lifts, corresponding with the wipers upon the wallower.

5, another rail in front, for carrying the detents which hold up the pestles when not acting. It is marked 14, in fig. 464.

6, a beam a little way behind the pestles; to this are fixed the pulleys for the ropes, which lift and stop the pestles. It is represented by 16, in fig. 464.

7, the said pulleys with their ropes.

8, the driver which strikes the wedge that presses the oil.

9, the discharger, a stamper which strikes upon the inverted wedge, and loosens the press.

10, the lower rail with its cross-pieces, forming the lower guides of the pestles.

11, a small cog-wheel upon the wallower for turning the spatula, which stirs about the oil-seed in the chauffer-pan. It has 28 teeth, and is marked No. 6, in fig. 464.

12, the four standards, mortised below into the block, and above into the joists and beams of the building.

13, the six mortars hollowed out of the block itself, and in shape pretty much like a kitchen-pot.

14, the feet of the pestles rounded into cylinders, and shod with a great lump of iron.

15, a board behind the pestles, standing on its edge, but inclining a little backwards. There is such another in front, but not represented here. These form a sort of trough, which prevents the seed from being scattered about by the fall of the pestles, and lost.

16, the first press-box, (also hollowed out of the block,) in which the grain is squeezed, after it has come for the first time from below the mill-stones.

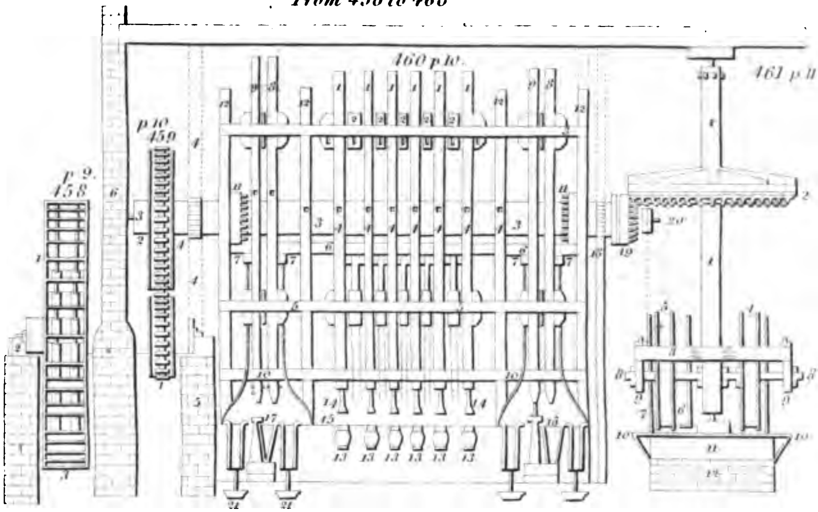
17, the second press-box, at the other end of the block, for squeezing the grain after it has passed a second time under the pestles.

18, frame of timber for supporting the other end of the wallower in the same manner as No. 4, fig. 459.

19, small cog-wheel on the end of the wallower, for giving motion to the mill-stones; it has 28 teeth.

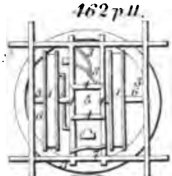
OIL, COLOUR & INDIGO MILLS

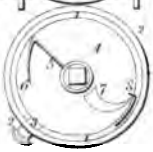
*From 458 to 468 **



458 p 9. 459 p 10. 460 p 10. 461 p 11.

462 p 11.





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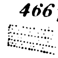
465 p 11.

466 p 11.



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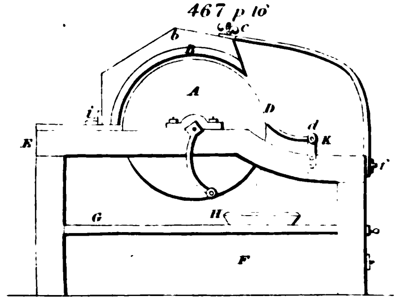

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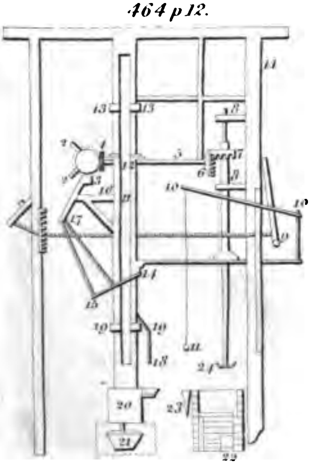

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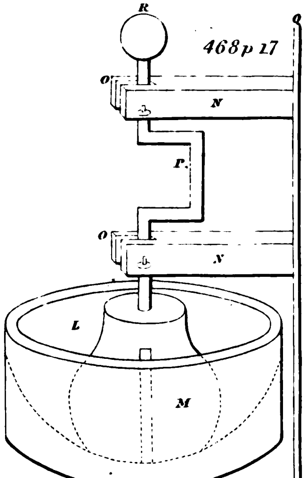

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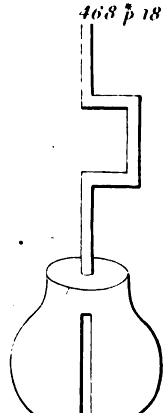


20, gudgeon of the wallower, bearing on a bell-metal socket fixed in the wall.
21, vessels for receiving the oil from the press-boxes.

Fig. 461, Elevation and mechanism of the mill-stones.

1, upright shaft, carrying the great cog-wheel above, and the runner mill stones below in their frame.
2, cog-wheel of 76 cogs, driven by No. 19 of fig. 460.
3, the frame of the runners.
4, the innermost runner, or the one nearest the shaft.
5, outermost ditto, being farther from the shaft.
6, the inner rake, which collects the grain under the outer runner.
7, the outer rake, which collects the grain under the inner runner. In this manner the grain is always turned over and over, and crushed in every direction. The inner rake lays the grain in a slope, of which fig. 465 is a section; the runner flattens it, and the second rake lifts it again, as is marked in fig. 466; so that every side of the grain is presented to the mill-stone, and the rest of the legger or nether mill-stone is so swept by them, that not a single grain is left on any part of it. The outer rake is also furnished with a rag of cloth, which rubs against the border or hoop that surrounds the nether mill-stone, so as to drag out the few grains which might otherwise remain in the corner.
8, the ends of the iron axle which passes through the upright shaft, and through the two runners. Thus they have two motions; first, a rotation round their own axis; secondly, that by which they are carried round upon the nether mill-stone, on which they roll. The holes in these mill-stones are made a little wide; and the holes in the ears of the frame, which carry the ends of the iron axes, are made oval up and down. This great freedom of motion is necessary for the runner mill-stones, because frequently more or less of the grain is below them at a time, and they must therefore be at liberty to get over it without straining, and perhaps breaking, the shaft.
9 and 10, the border or hoop which surrounds the nether mill-stone.
11 and 12, the nether mill-stone and masonry which support it.

Fig. 462, plan of the runner mill-stones, and the frame which carries them round.
1, 1, are the two mill-stones.
3, 3, 3, 3, the outside pieces of the frame.
4, 4, 4, 4, the cross-bars of the frames, which embrace the upright shaft 5, and give motion to the whole.
6, 6, the iron axis upon which the runners turn.
7, the outer rake.
8, the inner ditto.

Fig. 463 represents the nether mill-stone seen from above.
1, the wooden gutter which surrounds the nether mill-stone.
2, the border or hoop, about six inches high all round, to prevent any seed being scattered.
3, an opening or trap-door in the gutter, which can be opened or shut at pleasure; when open, it allows the bruised grain, collected in and shoved along the gutter by rakes, to pass through into troughs placed below to receive it.
4, portion of the circle described by the outer runner.
5, portion of the circle described by the inner one. By these we see that the two stones have different routes round the axis, and bruise more seed.
6, the outer rake.
7, the inner ditto.
8, the sweep, making part of the inner rake, occasionally let down for

sweeping off all the seed when it has been sufficiently bruised. The pressure and action of these rakes is adjusted by means of wooden springs, which cannot be easily and distinctly represented by any figure. The oblique position of the rakes, (the outer point going foremost,) causes them to shove the grain inwards, or toward the centre, and at the same time to turn it over somewhat in the manner as the mould-board of a plough shoves the earth to the right hand, and partly turns it over. Some mills have but one sweeper; and indeed there is great variety in the form and construction of this part of the machinery.

Fig. 464, profile of the pestle-frame.

1, section of the horizontal shaft.

2, three wipers for lifting the pestles.

3, little wheel of 28 teeth for giving motion to the spatula.

4, another wheel which is driven by it, having 20 teeth.

5, horizontal axle of ditto.

6, another wheel on the same axle, having 13 teeth.

7, a wheel upon the upper end of the spindle, having 12 teeth.

8, two guides, in which the spindle turns freely, and so that it can be shifted higher and lower.

9, a lever, movable round the piece No. 14, having a hole in it at 9, through which the spindle passes, turning freely. The spindle has in this place a shoulder, which rests on the border of the hole 9, so that by the motion of this lever the spindle may be disengaged from the wheel-work at pleasure; this motion is given to it by means of the lever 10, 10, movable round its middle. The workman employed at the chauffer pulls at the rope 10, 11, and thus disengages the spindle and spatula.

11, a pestle seen sidewise.

12, the left of ditto.

13, the upper rails, marked No. 3, in fig. 460.

14, the rail, marked No. 5, in fig. 460. To this are fixed the detents, which serve to stop and hold up the pestles.

15, a detent, which is moved by a rope at its outer end.

16, a bracket behind the pestle, having a pulley through which passes the rope going to the detent 15.

17, the said pulley.

18, the rope at the workman's hand, passing through the pulley 17, and fixed at the end of the detent 15.

This detent naturally hangs perpendicular by its own weight. When the workman wants to stop a pestle, he pulls at the rope 18, during the rise of the pestle. When this is at its greatest height, the detent is horizontal, and prevents the pestle from falling, by means of a pin projecting from the side of the pestle, which rests upon the detent, the detent itself being held in that position by hitching the loop of the rope upon a pin at the workman's hand.

19, the two lower rails, marked No. 10, fig. 460.

20, great wooden, and sometimes stone, block, in which the mortars are formed, marked No. 21, fig. 460.

21, vessel placed below the press-boxes for receiving the oil.

22, chauffer, or little furnace, for warming the bruised grain.

23, backet in front of the chauffer, tapering downwards, and opening below in a narrow slit. The hair-bags on which the grain is to be pressed after it has been warmed in the chauffer, are filled by placing them in this backet. The grain is lifted out of the chauffer with a ladle, and put into these bags; and a good quantity of oil runs from it through the slit at the bottom into a vessel set to receive it.

24, the spatula attached to the lower end of the spindle; and turning round among the grain in the chauffer-pan, and thus preventing it from sticking to the bottom or sides, and getting too much heat.

The first part of the process is bruising the seed under the runner-stones; that this may be more expeditiously done, one of the runners is set about two-thirds of its own thickness nearer the shaft than the other; thus they have different treads, and the grain, which is a little heaped towards the centre, is thus bruised by both. The inner rake gathers it up under the outer stone into a ridge, of which the section is represented in fig. 465; the stone passes over it, and flattens it. It is gathered up again into a ridge, of the form of fig. 466, under the inner stone by the outer rake, which consists of two parts; the outer part presses close on the wooden border which surrounds the nether stone, and shoves the seed obliquely inwards, while the inner part of this rake gathers up what has spread towards the centre. The other rake has a joint near the middle of its length, by which the outer half of it can be raised from the nether stone, while the inner half continues pressing on it, and thus scrapes off the moist paste. When the seed is sufficiently bruised, the miller lets down the outer end of the rake; this immediately gathers the whole paste, and shoves it obliquely outwards to the wooden rim, where it is at last brought to a part that is left unboarded, and it falls through into troughs placed to receive it. These troughs have holes in the bottom, through which the oil drips all the time of the operation. This part of the oil is directed into a particular cistern, being considered as the purest of the whole, having been obtained without pressure, by the mere breaking of the hull of the seed.

In some mills this operation is expedited, and a much greater quantity of this best oil is obtained, by having the bed of masonry which supports the legger formed into a little furnace, and gently heated; but the utmost care is necessary to prevent the heat from becoming considerable. This, enabling the oil to dissolve more of the fermentable substance of the seed, exposes the oil to the risk of growing soon very rancid; and in general it is thought a hazardous practice, and the oil does not bring so high a price.

When the paste comes from under the stones, it is put into the hair-bags, and subjected to the first pressing. The oil thus obtained is also esteemed of the first quality, scarcely inferior to the former, and is kept apart, (the great oil-cistern being divided into several portions by partitions.)

The oil-cakes of this pressing are taken out of the bags, broken to pieces, and put into mortars for the first stamping.

Here the paste is again broken down, and the parenchyma of the seed reduced to a fine meal; thus free egress is allowed to the oil from every vesicle in which it is contained. But it is now rendered much more clammy by the forcible mixture of the mucilage, and even of the finer parts of the meal. When sufficiently pounded, the workman stops the pestle of a mortar, when at the top of its lift, and carries the contents of the mortar to the first chauffer-pan, where it is heated to about the temperature of melting bees'-wax, (this, we are told, is the test,) and all the while stirred about by the spatula. From thence it is again put into hair-bags, in the manner already described; and the oil which drops from it during this operation is considered as the best of the second quality, and in some mills is kept apart. The paste is now subjected to the second pressing, and the oil is that of the second quality.

All this operation of pounding and heating is performed by one workman, who has constant employment by taking the four mortars in succession. The putting into the bags, and conducting the pressing, gives equal employment to another workman.

In the mills of Picardy, Alsace, and most of Flanders, the operation ends here; and the produce from the chauffer is increased, by putting a spoonful or two of water into the pan among the paste.

But the Dutch take more pains. They add no water to the paste of this their first stamping; they say that this greatly lowers the quality of the oil. The cakes which result from this pressing, and are then sold as food for cattle, are still fat and soft. The Dutch break them down, and subject them to the pestles for the second stamping; these reduce them to an impalpable paste stiff like clay. It is lifted out, and put into the second chauffer-pan; a few spoonfuls of water are added, and the whole kept for some time as hot as boiling water, and carefully stirred all the time. From thence it is lifted into the hair-bags of the last press, subjected to the press, and a quantity of the lowest quality is obtained, sufficient for giving a satisfactory profit to the miller. The cake is now perfectly dry and hard, like a piece of board, and sold to the farmers. Nay, there are small mills in Holland which have no other employment than extracting oil from the cakes which they purchase from the French and Brabantees: a clear indication of the superiority of the Dutch practice.

The nicety with which that industrious people conduct all their business is remarkable in this manufacture.

In their oil-cisterns, the parenchymous part, which unavoid-

ably gets through, in some degree, in every operation, gradually subsides, and the liquor, in any division of the cistern, comes to consist of strata of different degrees of purity. The pumps which lift it out of each division are in pairs; one takes it up from the very bottom, and the other only from one-half the depth. The last only is barrelled up for the market, and the other goes into a deep and narrow cistern, where the dreg again subsides, and more pure oil of that quality is obtained. By such careful and judicious practice, the Dutch not only supply themselves with this important article, but annually send considerable quantities into the very provinces of France and Flanders, where they buy the seed from which it is extracted. When we reflect on the high price of labour in Holland, on the want of timber for machinery, on the expense of building in that country, and on the enormous expense of wind-mill machinery, both in the first erection and the subsequent wear and tear, it must be evident that oil-mills erected in England on water-falls, and after the Dutch manner, cannot fail of being a great national advantage. The chatellenie or seigneurie of Lille alone makes annually between 30,000 and 40,000 barrels, each containing about 26 gallons.

What is here delivered is only a sketch. Every person acquainted with machinery well understands the general movements and operations; but the intelligent mechanic well knows that operations of this kind have many minute circumstances which cannot be described, and which, nevertheless, may have a great influence upon the whole. The rakes in the bruising-mill have an office to perform which resembles that of the hand, directed by a careful eye and unceasing attention. Words cannot convey a clear notion of this; and a mill constructed from the best drawings, by the most skilful workman, may gather the seed so ill, that the half of it shall not be bruised after many rounds of the machinery. This produces a scanty return of the best oil, and the mill gets a bad character; the proprietor loses his money, is discouraged, and gives up the work. There is no security but by procuring a Dutch millwright, and paying him with the liberality of Britons. Such unhoped-for tasks have been performed of late years by machinery, and mechanical knowledge and invention is now so generally diffused, that it is highly probable we should soon excel our teachers in the branch; but this very diffusion of knowledge, by encouraging speculation among the artists, makes it a still greater risk to erect a Dutch oil-mill, without having a Dutchman, acquainted with its most improved present form, to conduct the work.

COLOUR AND INDIGO-MILLS.

The reducing of earths, vegetable substances, and metallic oxyds to an impalpable powder, is still in a great degree effected by manual labour, by moving a heavy stone with a smooth surface, called a muller, upon a slab of the same material. To effect this work upon a large scale, and to secure the workman from the ill effects of the poisonous and noxious vapours of the paint, which is not unfrequently ground with litharge of lead, Mr Rawlinson, of Derby, has invented a machine which we here describe. It is represented in fig. 467.

A, the roller, or cylinder, made of any kind of black marble. Black marble is esteemed the best, because it is hardest, and takes the best polish. B, the concave muller, covering one-third of the roller, and of the same material, fixed in a wooden frame *b*, which is hung to the frame E at *i i*. C is a piece of iron, about an inch broad, to keep the muller steady, and is fixed to the frame with a joint at *f*. The small binding screw with a fly-nut, which passes through the centre of the iron plate at *c*, is for the purpose of laying more pressure upon the muller, if required, as well as to keep it steady. D is a taker-off, made of a clock-spring, about half an inch broad, and fixed similar to a frame-saw in an iron frame K, in an inclined position to the roller, and turning on pivots at *d d*. G is a slide-board to draw out occasionally, to clean, &c. if any particles of paint should fall from the roller; it also forms itself for the plate H, to catch the colour as it falls from the taker-off. F is a drawer for the purpose of containing curriers' shavings, which are used for cleaning paint-mills. E is the frame.

Previously to putting the colour in the mill, it must be pulverized in a mortar, covered in the manner of the chemists, when they levigate poisonous drugs, or rather in an improved mill, used at Manchester, by Mr Charles Taylor, for grinding indigo in a dry state, a drawing and description of which is annexed. After undergoing this process of dry-grinding, which is equally necessary for the marble slab now in use, it is mixed with either oil or water, and is with a spatula, or palette-knife, put on the roller, near to the top of the concave muller. Motion being given to the roller, it, without any difficulty, carries the colour under the muller, and in a few revolutions spreads it equally over the surface. When ground sufficiently, it is taken off, both cleanly and expeditiously, by the taker-off described, which, for that purpose, is held against the roller, while the roller is turned the reverse way. The muller only requires to be cleaned when the workman changes the colour, or ceases from the operation; it is then turned back, being hung on pinions to the frames at *i i*, and is cleaned with a palette-knife or spatula; afterwards a handful

of curriers' shavings is held against the roller, which, in two or three revolutions, cleans it effectually.

The roller of Mr Rawlinson's machine is sixteen inches and a half in diameter, and four inches and a half in breadth; and the concave muller which it works against covers one-third of the roller. It is therefore evident, that, with this machine, he has seventy-two square inches of the concave marble muller in constant work on the paint, and that he can bring the paint much oftener under the muller in a given space of time than with the common pebble muller, which, being seldom more than four inches in diameter, has scarcely sixteen square inches at work on the paint, whereas the concave muller has seventy-two.

The quantity ground at once in the mill must be regulated by the degree of fineness of which it is required, that which is the finest requiring the smallest quantity to be ground at once. The time requisite for grinding is also dependent upon the state of fineness; but Mr Rawlinson observes, that his colour-grinder has ground the quantity of colour which used to serve him per day in three hours; the colour also was more to his satisfaction, and attended with less waste.

When the colour is ground, Mr Rawlinson recommends, instead of drawing the neck of the bladder up close in the act of tying it, to insert a slender cylindrical stick, and bend the bladder close round it; this, when dry, will form a tube or pipe, through which, when the stick is withdrawn, the colour may be squeezed as wanted, and the neck again closed by replacing the stick. This is not only a neater and much more cleanly mode than the one usually adopted, that of perforating the bladder, and stopping the hole with a nail, or, what is more common, leaving it open, to the detriment of the colour; but the bladder, not being injured, may be repeatedly used for fresh quantities of colour. The barrel of a quill may be inserted in the neck of the bladder, as a substitute for the stick, and the end being cut off, may be closed by a small piece of wood.

In order to make the whole of the process of colour-grinding complete, we shall here insert a description of the indigo-mill used by Mr Charles Taylor, of Manchester, for grinding indigo in a dry state, which may with equal advantage be similarly employed for colours. It is represented in figs. 468 and 468*.

L, fig. 468, represents a mortar, made of marble or hard stone; one made in the common way will answer. M, a muller, or grinder, nearly in the form of a pear; in the upper part of which an iron axis is firmly fixed,

which axis at the parts N N turns in grooves or slits, cut in two pieces of oak, projecting horizontally from a wall, and when the axis is at work are secured in the grooves by iron pins O O. P, the handle, which forms a part of the axis, and by which the grinder is worked. Q, the wall in which the oak pieces N N are fixed. R, a weight, which may occasionally be added if more power is wanted.

Fig. 468*, shows the muller or grinder, with its axis separate from the other machinery; its bottom should be made to fit the mortar. S is a groove cut through the stone.

On grinding the indigo, or similar substance, in a dry state, in this mill, the muller being placed in the mortar and secured in the oak pieces by the pins, the indigo to be ground is thrown above the muller into the mortar; on turning the handle of the axis, the indigo, in lumps, falls into the groove cut through the muller, and is thence drawn under the action of the muller, and propelled to its outer edge within the mortar, whence the coarser particles again fall into the groove of the muller and are again ground under it; which operation is continued till the whole of it is ground to an impalpable powder; the muller is then easily removed, and the colour taken out.

A wood cover in halves, with a hole for the axis, is usually placed upon the mortar, during the operation, to prevent any loss to the colour, or bad effects to the operator.

POTTERY.

The clays best adapted for the manufacture of earthenware are excavated in Dorsetshire, and the next in quality in Devonshire.

The natural compounds, called clays, consist generally of pure clay, or alumine, combined with either silex or lime, and sometimes magnesia, and the oxyd of iron. The presence of the magnesia may easily be detected by its imparting a soapy feel; and the iron by the clay burning to different shades of red, proportionate to the quantity it contains. The magnesia has obtained the name of soap-rock, and a marked variety of it steatite.

The clay is first put into a trough about five feet long, by three wide, and 2½ deep, with a certain proportion of water, and subjected to the process called *blunging*, which is obviously akin to blending, or mixing. This is performed with a long piece of wood formed in the shape of a blade at one end, and with a cross-handle at the other. The bladed end is put into the trough, and moved backwards and forwards, up and

down, with violence, till the clay be broken and well levigated. The coarser particles of the clay sink to the bottom of the trough, while the finer part remain suspended in the solution; and clay is continued to be added until the solution has acquired the consistence of thick cream. This thick liquid is passed into a large tub, and afterwards through fine hair and silk lawn sieves, and then mixed with certain proportions of a liquid of ground calcined flints and Cornish stone, which, likewise, have been passed through silk lawn sieves.

The china clay, which is used in every kind of earthenware except the cream colour, is sometimes put into the mass, and blunged with it; at other times it is put into another tub, and blunged separately, and is then mixed in proper proportions with the other slip.

The slip is now passed into another large stone or wood cistern, and the parts, which have not been previously, are now added, and the whole is passed through fine lawn into a reservoir, from whence it is pumped upon the slip-kiln.

When a steam-engine is used, the clay is thrown into a vertical cast-iron cone, about two feet wide at top, and six feet deep. Inside of this cone are fixed strong knives, having a spiral arrangement and inclination, and radiating towards the centre. In the centre of these is worked a perpendicular shaft, with similar radiating knives, so that the knives, by the revolution of the shaft, cut in pieces every thing that is thrown into the cone, and force downward, agreeably to the nature of the screw, whatever may be put in, till it is discharged through an orifice at the bottom.

The clay, thus reduced to powder, is next subjected to the process of blunging. For this purpose it is thrown into a large circular vat, or cistern, having a strong vertical shaft of wood, with arms formed like a gate as radii, worked by the power of the steam-engine. The vat is nearly filled with proper proportions of water and clay, which, by the rapid motion of the shaft, becomes well levigated and mixed; clay or water being added until the liquid is of the consistence of cream. The liquid is then passed along several trunks, at the end of each of which is fixed a fine hair or lawn sieve. These sieves have a quick horizontal motion communicated to them by crank machinery, which causes the slip to pass through into a large reservoir, where it remains till pumped upon the kiln.

The flint in its crude state is the common flint used for striking fire, which consists principally of pure silex. The

method of calcining it is, by placing it in a small conical kiln, about nine feet deep, and altogether not much unlike that used to burn limestone. When red-hot it is taken out of the kiln and thrown into cold water, in order to lessen its aggregation, and make it easier to reduce to powder. The flint is next broken into pieces, either by manual labour, or machinery. Where manual labour is employed one man is found adequate to break per diem enough to supply two flint-pans, 12 feet diameter.

In the other process the flints are put on a strong iron grating, and are struck by large hammers, moved by machinery, till they be so reduced as to fall through the grating into a cavity, from whence they are taken to the flint-mill.

The *flint-mill* consists of a large circular vat, about 30 inches deep, with a step fixed in the centre at the bottom for the axis of a vertical wood or iron shaft. The upper end of the shaft is surmounted by a large crown cog-wheel, to which the moving power is applied. The lower end has, at right angles, four leaves, or paddles, like arms, upon which are fixed chert-stones. Large blocks of chert-stone are also placed in the vat. The flints being put into the vat, the whole is covered with water, to prevent any dust from arising, which had formerly a very injurious effect. Power being communicated to the shaft, the chert-stones are carried round with considerable velocity, and the calcined flints, being of a very fragile nature, are, by their reciprocal action, reduced to an inpalpable powder.

This semi-fluid is put into another vat, that has a similar vertical shaft, and when a large quantity of water has been introduced, the power is applied and the whole is well levigated. In this process, the weighty particles sink to the bottom, and the finest remain in suspension; which are then passed into a reservoir that has certain apertures for drawing off the surplus water, till it has subsided to a state fit for the potter's use. This a very important process, and is attended with some difficulty. It is at present best performed by Mr Sampson Hanley, of Sandon Mill.

The manufacturer should be very choice in selecting the stones to be employed in the grinding; for should they contain calcareous carbonates, such parts will be abraded, and by mixing with the silicious matter will, in a subsequent process, prove a serious injury.

A few years ago a loss to the amount of several thousand pounds was experienced by some manufacturers, who had very injudiciously purchased stones that had been ground by

a person ignorant of the art, and who had employed stones for the grinding containing carbonate of lime.

The average weight of an ale pint measure of the pulp of flint is 32 oz.; and of clay 24 oz.

In some manufactories the pulps are mixed together in a large vat, by a process similar to that first described of mixing the clay with the water. But however the mixing be accomplished, great attention must be paid to the relative specific gravity of each fluid, and more of the solution of the flint, or the clay, must be added, till a pint of the mixture weighs the determined number of ounces. It is by the consistence and weight of these materials that the manufacturer is enabled to ascertain the proper proportions requisite for each kind of pottery; and it is from these that he can calculate whether there be a probability of making any improvement that will yield him a profitable return.

When the proper proportions of slop clay and flint have been well blunged together, the liquid is pumped out of the reservoir on the top of the slip-kiln.

The *slip-kiln* is a kind of trough formed of fire-bricks, of various sizes, from 30 to 60 feet in length, by from 4 to 6 in breadth, and about twelve inches in depth. Flues from the fire-places pass under these troughs, and the bricks of which they are formed being bad conductors of heat, a slow and advantageous process of evaporation is carried on, which gives uniform consistence to the mass.

The porcelain clay is never allowed to boil, but is carefully evaporated at a slow heat on a plaster-kiln; the gypsum being run on old moulds pulverized, and thus forming a level surface.

The slip-maker carefully attends to the evaporation, and at proper intervals turns over with a paddle the thickened mass from one end to the other, else the part nearest to the bricks would become hard, while the surface were fluid. To regulate the heat three different thicknesses of bricks are employed, the thickest being placed nearest to the fire-place, where is the greatest excess of heat.

When a sufficient quantity of the moisture is evaporated, which is indicated by the cessation of apparent effervescence, or the absence of air-bubbles on the surface of the mass, the composition, still called clay, is removed to the flags.

If the evaporation were continued longer the clay could not be formed into the required shapes, either on the wheel, or by the vat, but would be what is called knotty, lumpy.

The clay is cut out of the kilns in square masses, by means

of spades, and is thrown into a heap, where is attained an uniform temperature of cold and moisture. The longer it can lie after coming off the kiln the better it will be; but the time is arbitrarily varied by the want of room, of time, or of capital.

When the clay is first taken off the kiln, it is, partly from the air-bubbles remaining in it, and partly from the non-dissipation of the heat requisite for evaporation, too soft to be worked. On this account it is well incorporated together, or tempered by beating with wooden mallets. It is then cut into small pieces with a paddle, not much unlike a spade, and from the paddle each piece is, with all the force of the workman, propelled upon the mass. These two operations are repeated until a proper consistence pervades, and the whole is supposed to be well-tempered.

When the clay is required for the thrower, the process of *slapping* follows next. This is performed by a strong man, who places a large mass, about half a hundred weight, upon a convenient and strong bench. He then, with a thin brass wire, cuts the mass through, and taking up the piece thus cut off, he, with his utmost strength, casts it down again on the mass below; and continues the operation as long as is considered necessary.

This is a very laborious process, and is absolutely necessary to drive out any air-bubbles which may happen to remain in the mass after it has been beaten: for should any be left in the clay the pieces on being fired would blister and spoil, owing to the rarefaction of the air by the heat. On this very important account, the process is continued until the mass, wherever cut by the brass wire, exhibits a surface, perfectly smooth and homogeneous.

In several of the largest manufactories the labour of slapping the clay is superseded by mechanical contrivance. A quantity of the mass from the slip-kiln, when rather cold, is thrown into a large conical iron vessel, (similar to that employed in breaking the clay,) with strong knives fixed in it, with a given inclination, with corresponding knives radiating from a vertical shaft, moved by the steam engine with a slow and regular motion. By these means, all the clay put into the cone is very minutely separated, and pressed down, as by a screw, so that the mass just cut, and divided, is instantly squeezed together again, and is then similarly affected by other knives below. At the bottom of the cone on one side is a quadrangular aperture, through which the clay is gradually forced, and is by a thin brass wire cut into brick-shaped

pieces of from 50 to 60 pounds weight. Sometimes these masses are for particular purposes returned into the cone, and undergo the process a second time.

Wedging the clay is a similar process, though never omitted by the *presser*, or *squeezer*, however well it may have been beaten by the slip-maker. The presser cuts off, with a thin brass wire, a piece of clay from the mass, which he slaps forcibly between the palms of his hands, and then with great violence throws it on the board; continuing the operation until the commixture is so complete that there is no probability of any air-bubbles remaining. If one of the two first pieces of clay had been white, and the other black, the mass, after undergoing these processes, would present wherever cut a uniform gray colour.

It is owing to the mass being properly wedged that that consistency and tenacity is obtained, which enables the workman to employ it with facility and confidence in the fabrication of the different pieces of pottery which he has to make. The clays for vessels require different degrees of wedging; and some kinds require much more careful and continued wedging than others.

The clay may now be considered ready for the *thrower*. The *throwing-wheel*, or, with greater propriety, the *throwing-engine*, consists of a large vertical wheel, having a winch or handle affixed to it, and a groove on the rim for the introduction of a cord. The whole is fixed upon a strong movable plank, by which the cord can be slackened or tightened at pleasure, and then upon a frame nearly triangular, or half-oval, and about 30 inches in height, with a broad ash hoop placed edgewise on the fore part, about six inches deep.

In the centre of this frame is a vertical spindle, with its lower end fitted and working in a step. A little above this is a pulley, with grooves for three speeds of the propelling power, connected with the throwing-wheel by means of a cord or belt; and a little higher up is a pivot turned to fit and work in a collar step. On the upper end is a stout wooden circular top, which revolves horizontally, and is in diameter about seven inches; and other tops of different diameters are in readiness to be fixed on, according to the intended size of the vessel to be made.

The engine is set in motion by manual labour, applied at the winch, and another man, called the *baller*, cuts with a thin piece of brass wire a piece of clay from the mass on the bench, and forms it into a ball, which he gives to the thrower. If china is to be made, the baller, previously to forming the clay

into a ball, breaks it in two, and violently slaps it together between the palms of his hands. The thrower forcibly throws the ball down upon the horizontal revolving top of the engine, and dipping his hands frequently into water, to prevent the clay adhering to them, fashions it into a long thin column, which he again forces down into a lump, and continues to repeat the operation until he is satisfied that the air-bubbles, which might have remained in the clay after the processes of slapping and balling, are dispelled.

The thrower now directs the speed of the engine to be lessened, and with his fingers, which he frequently dips in water, he gives the first form to the vessel; then with different *profiles*, or *ribs*, he forms the inside of the vessel into whatever shape may be required, and smooths it by removing the *slurry*, or inequalities.

If a number of vessels of the same size be required, the thrower has a peg placed as a guage, which serves to direct him in the width and depth; and when the vessel has two diameters, as the neck and body in a jug, he has two pegs to guide him.

The thrower forms all circular vessels in this manner; and he employs different sized ribs to finish the shapes, or swell of the edge, &c. When he has thus given the first form to the clay, he cuts the vessel from the head of the engine, by passing a thin brass wire through the lowest parts of the clay, which separates it, and allows it to be easily lifted off, and placed by the baller on a long board or shelf, where it is left to dry a little preparatory to being turned, or properly smoothed and shaped.

Where large vessels are made, and the power of a steam-engine applied, according to Mr J. Wedgwood's method, a pair of vertical cones is used, the apex of the one being opposite to the vertex of the other. One of these cones is driven directly by the steam-engine, and transmits motion to the other by means of a broad belt or strap of leather, which is always equally tight in any and every part of the cones, because they are equal and reversed; but it is plain, that the speed of the driven cone will vary much according as the belt is at the top or the bottom of the driving cone. When the belt is at the bottom or thinnest part of the driving cone, the driven cone moves very slowly; as the belt is made to ascend, the speed of the driven cone increases, and ultimately attains its maximum when the belt is at the top. A strap is attached from the driven cone to the spindle of the throwing engine, and the speed is varied at the thrower's

pleasure, by a boy working a directing winch. When the article is finished, the machine is thrown out of geer.

For forming saucers, and other small circular articles, there has been recently introduced a small vertical shaft, called a *jigger*, on the top of which is a turned head, suited to receive the mould on which the saucers, &c. are to be formed.

When the clay is in one peculiar state call the *green state*, it is the most suitable and proper for performing to the greatest advantage the remaining operations and processes of turning, handling, trimming, &c.

The *turning-lathe* is the same as used by wood-turners. The end of the spindle, outside the headstock, has a screw thread, upon which is screwed *chocks* of wood, of a tapered form, and of different diameters, according to the size of the interior of the articles of pottery to be turned. The turner stands very steady, and receives from an attendant the vessel to be turned, which he fixes upon the chock, and then with a tool presses the edges close down.

The tools are of different sizes, from one quarter of an inch to two inches in breadth, and six inches in length, made of thin iron, like hoop-iron, the end for cutting being turned up about a quarter of an inch, and ground sharp.

Motion being communicated to the lathe, the turner applies his tool or tools to the various parts of the surface that require reduction of substance, either as regards thickness, or the suitable shapes of rims, feet, &c. When this is completed, a contrary motion is communicated to the spindle, during which the turner applies the flat part of his tool to the vessel, and by gentle pressure gives it a smooth surface, and solid texture.

In the turning-lathes moved by steam some particular arrangements are made. A horizontal shaft runs the whole length of the room; and opposite to each lathe is a drum, which communicates motion to a set of pulleys, of various sizes, fixed on an arbor or shaft, by means of a leather belt. Upon this arbor, or shaft, is a loose pulley, connected by a crossed belt with a small pulley fixed on the spindle of the lathe, which evidently will, whenever the strap from the drum is directed upon the loose pulley, receive a retrograde motion. The spindle has pulleys counter to those fitted on the arbor, and as they are ever revolving, the directing of the belt from them to the spindle, by a guide moved by the workman's foot, will increase or diminish the speed during the turning of the vessel under operation; and when it is finished, by moving the drum-strap on another pulley, retro-

grade motion is given, during which the turner smooths off his article as before noticed.

The *engine-lathe* is of the kind employed to give unto circular articles of hardware a milled edge; consequently, it differs from the other, or common lathe, in the formation of the end of the spindle, and the appendages to the headstock. Certain thin circular plates of steel, into whose edges are cut, at regular intervals, and of different degrees of breadth, deep incisions, are made to screw very firmly on the end of the spindle above the chock. The collar-step of the spindle is so fitted that it can be effected by a screw pin, which gives it the requisite horizontal shuffling motion. Opposite to the steel-plate is fixed an iron piece that fits into the incisions. The turner's tools are filed to give the particular form to the designed ornament, and the vessel, having been previously turned in the plain way, receives a shuffling motion backwards and forwards as the spindle slowly revolves, and only when the incision admits the piece of iron will the vessel be in contact with the tool of the workman. When the iron is against the rim the surface remains untouched by the tool. Numerous very elegant and curiously indented porcelain articles are formed by the engine-lathe. The black Egyptian circular tea-pots will exemplify every species of engine-lathe turning.

As the vessels as soon as turned are in the best green state, they are, as soon as possible, passed to the *handler*, who fixes the spouts, handles, and all other requisite appendages. Such spouts, handles, or appendages, as are in any way curved, oval-shaped, or ornamented, are formed in moulds of two or more parts, as will be seen hereafter when speaking of squeezing.

For handles, and some other articles of appendage, a press is used, consisting of an iron cylinder, six inches wide, and ten inches deep. This cylinder has a strong bottom, with an aperture in the centre, to which is made to fit differently shaped plugs. It has a piston acting by a screw, that works in a bent iron bow, fastened to the block on which the cylinder rests. The aperture being supplied with a plug of the required form, some clay is put into the cylinder, and the piston forced down, by turning the screw, which causes the clay to protrude through the aperture in the shape required. The workmen cut it into lengths, as wanted, and bend it into the required form, and when sufficiently dry, affix it to the vessel by slip. Slip is likewise used to affix all other appendages. When a tube is wanted, a pin is fixed

in the clay that protrudes through the aperture of the cylinder, a pin is fixed above the centre of the plug. The vessel, being allowed a short time to dry, is cleared of all the superfluous clay by a knife. The vessel is then trimmed with other tools, and the whole of the joints cleaned off with a moist sponge, which, while it carries off all excrescences, gives to the whole uniform moisture.

We shall, previously to mentioning the process of squeezing, take notice of the modeller and the mould-maker, whose occupations are very distinct branches of the art.

The *modeller* has great scope for the exertion of natural and acquired ability, taste and ingenuity: for on him depends the elegance, size, figure, adaptation, and correct arrangement of suitable ornaments. His business consists in taking a large lump of well-tempered clay, and modelling it, by continued carvings, with a sharp narrow-bladed knife, into the rough figure: he then commences the trimming process, by removing all excrescences, inserting any additions, and finally, with a great variety of suitable tools, made of ivory, wood, or metal, gives to the whole the several touchings and retouchings requisite for finishing.

The modellers of the present day have attained much excellence, and as a proof we need only to state, that many who have seen the *Portland* or *Barberini vase*, (for modelling of which Mr Wedgwood is said to have paid Webber the enormous sum of four hundred pounds,) declare, that any good modeller would now execute the whole himself in less than a month, and with a proper assistant in a fortnight. The branch of modelling, however, is by far more common now than it was in the time of Mr Wedgwood; and good workmen obtain fair remuneration for their labour.

The *mould-maker* receives the model, and forms from it the requisite moulds, by employing plaster of Paris.

The gypsum or native sulphate of lime plaster is first ground in a mill, similar to a flour-mill. It is then put in a long trough, under which runs a flue communicating with the fire, to effervesce until all the water is expelled. This process is called both *boiling* and *burning*. The workman has his mouth and nose always well covered, to prevent his inhaling any of the dusty particles, which would, if taken inwardly, be very prejudicial to the lungs.

The mould-maker forms, and secures by a broad strap, a casing of thick clay round the model: he then mixes in a jug, containing a certain quantity of water, the proper portion of the soft impalpable powder or plaster, and stirring it

quickly, that the water may have an opportunity of pervading it thoroughly, pours it upon and around the model: in some instances gently or briskly shaking the mass. Some heat is immediately given out, and the whole very soon becomes a compact mass. After standing a short time, the mould is easily separated from the model, and each part is placed in a stove to be dried.

When the moulds are found to be perfect, they are kept dry, by which they retain the property of absorbing moisture with great rapidity, so that the *squeezer* can often separate his work from them readily, and when this is the case, the mould is said to *deliver* easily.

In some of the principal manufactories, large slabs of plaster are fitted up as shelves, which serve the twofold purpose of holding the newly-formed articles, and of facilitating the drying, by absorbing a portion of the moisture.

The workman, called the *dish-maker*, who uses moulds, for dishes, plates, saucers, wash-bowls, or hollow ware, always cuts off from the mass a piece of clay according to the size and strength of the article he has to make. This he again cuts asunder, or breaks with his hands, repeating the operation of forcibly slapping them together, to prevent any air-bubbles from remaining in it. The piece is then laid on a flat surface of board or plaster, and the workman with a heavy lump of clay, with a level under-surface, adapted for holding in the hand, beats the clay to the thinness the vessel is intended to form. These pieces of clay are technically called *bats*.

For wash-bowls, dishes, or plates, the workman, called the *whirler*, uses a vertical spindle, surmounted with a circular block, ten inches diameter, and about two inches thick. On this he places his plaster-mould, and with a bat lays the clay properly upon it; he then with one hand gives motion to the whole, while with the other, dipped in water, he presses the clay very close to the plaster-mould: then, when any additional piece is required, as the ledge, or foot, it is joined on with slip, and firmly squeezed to the other clay. Afterwards a suitable thin tool or utensil of pot, of the profile of the inside, is applied, to give the proper shape and thinness. The sponge is now again employed to clean off all excrescences; the whole is cut to its size, finished with the sponge, and set to dry a little, and a horn tool is employed to trim it off.

The moulds are capable of being used five or six times in succession each day, because as soon as one has been charged

it is set in a stove to dry, and as the workman proceeds regularly, each is allowed equal time for drying.

When the bowls, dishes, or plates, are taken off the moulds, and have been pared round the edge with a thin bladed knife, they are slightly polished by the hand, and afterwards laid on each other in quantities of four, eight, twelve, or more, according to their size and strength, to dry and harden, preparatory to being placed in saggers for the biscuit-oven.

The *squeezer* generally uses moulds which have two or more parts. The moulds for figures have their parts numbered. He takes a bat of a proper size and thickness, and lays it in one part of the mould, then with a large sponge beats and well forces it into all the cavities; he next takes another part, on which is the bottom, and presses the two parts together; he then rolls a piece of clay, and forces it into those parts of the article where the mould joins together, and afterwards cleans off all the excrescences, and secures the parts by a leather strap, so that they cannot come asunder while the mould is in the stove, or on the shelf, to dry to the green state. When he takes the strap off, the parts of the mould are carefully separated, and the vessel finished, by the joints being pared, cleaned, and sponged. The spouts, handles, covers, ornaments on the outside, and figures, are similarly formed and finished off.

This part of the process was formerly performed by casting; but *casting* is now only employed for the most elegant irregular shapes, where strength is not important.

The very dry mould is well closed together, and strapped for security. Some clay is then mixed with pure water till it be reduced to a pulp of the consistence of cream. This is poured into the mould until it be filled, and the plaster, of which the mould is formed, absorbs the water from the clay that is contiguous to it, and leaves a coating of clay attached to the mould. The pulp is then poured out, and the coating allowed a short time to dry; a second charge of a much thicker consistence is then poured in, and forms a body sufficiently thick for the article intended, and when a coating is again formed, the remainder of the pulp is poured off, and the mould placed a short time near to a stove, and when sufficiently dried is separated, and the article left to dry to the green state: the seams of the joints are then smoothed off, and the article is finished by the skill of the workman, and when thoroughly dried is placed in a sagger for the biscuit-oven.

All the articles made in the clay by these various pro-

cesses, after being finished in reference to their shapes, figures, sizes, ornaments, &c. are placed on boards, and left to dry by the temperature of the apartment where they were made, or put into a drying-house, green-house, or stove.

The *sagger-maker** is expected to know the exact proportions of marl, old ground saggers, and sand, that are required to form the best saggers for either pottery or porcelain. Saggers are of different sizes, shapes, and depths, formed of a very porous composition, and capable of bearing, without being fused, a most intense heat. The bottom of each sagger has a thin layer of fine white sand, to prevent the pieces of pottery touching and adhering to it.

For porcelain flat ware, as plates, &c. the sagger is also firmly filled with very dry flint, to preserve each piece in its proper shape. When a sagger is filled with clay ware, on its outer edges are placed thick pieces of coarse clay, called *wads* from their being employed to wedge or closely join the interstice between two saggers, as well as to support the edges, and preserve equal pressure.

Each pile of saggers placed in an oven is called a *bung;* and the man who places the ware in the saggers, and the saggers in the oven, the *oven-man.*

The potter's oven, for both biscuit and gloss firings, is very much like that in which bricks and tiles are usually burnt in most parts of the kingdom; that is, a cylindrical form, surmounted by a dome. Around this oven are formed fire-places or mouths, whence the fire passes into horizontal flues in the bottom, and perpendicular flues, called bags, on the inside, and so ascends through all the interstices of the bungs of saggers, until the surplus escapes through the aperture in the dome of the oven.

Most ovens are surrounded by a high conical building, called a *hovel,* large enough to allow the man to wheel coals to the requisite places, and to pass along to supply each mouth with fuel; and at the same time to protect both him and the oven from rain or any other atmospheric inclemency.

The saggers are sometimes placed to dry in the sides of the hovel, and sometimes in a smoke house.

The biscuit-oven is always the largest upon the premises. The workman is called the *biscuit-fireman,* and is employed from 48 to 50 hours at a time. The heat is gradually in-

* The word "sagger" is by many supposed to be a corruption of safeguard; but we are disposed to date its origin to the Hebrew, from the word *sagar,* to burn. It is a baked earthen vessel into which others are placed when put into the kiln.

creased throughout the time, but porcelain does not require it so long, as it more readily allows the heat to be raised.

In different parts of the oven, where they can be easily extracted, rings of Egyptian black clay are placed, as trials, by which an experienced fireman can tell how much longer the process must be carried on, not within an hour, as indicated by Wedgwood's pyrometer, but within ten minutes. Hence the pottery district has a very pertinent proverb: "*Nothing beats a trial.*"

The name of the ware thus fired is *biscuit*, because of its being to appearance and feel like ship-bread when well baked; the surface is devoid of any appearance except that of a tobacco-pipe, sometimes tinged by the intense heat. When the saggers are taken out, the articles are carefully sorted, and all injured pieces are rejected.

If pottery were used in the biscuit state, it would, in some cases, be permeable to water; hence wine-coolers, *alcazaras*, are always in the biscuit state. The best size of wine-coolers is that which just admits the bottle, for then the air of the room can very little affect the water in the cooler, which consequently, by passing from the inner to the outer surface, effects the purpose sooner; a humid coating being thus presented to the action of the surrounding atmosphere, the evaporation causes a consequent quicker diminution of heat than could take place with a dry surface.

All articles of pottery which have but one colour, and many that have several, are in general ornamented either by the pencil, or by impressions taken from copper-plates. The former is called *blue*, or *biscuit-painting*, the latter *blue-printing*. Both processes take place on the biscuit, prior to the ware being dipped in the glaze. If the ware were not previously fired, and were capable of being handled about for the painting, the water, used to soften the colours, would soften the ware; and the impressions from plates could not be clearly, even if at all, transferred to the ware; water also could not be employed to wash off the paper, and the water which contains the components of the glaze would be absorbed by the clay body, which would by this means be rendered so soft as not to preserve its shape in the oven.

It has been thought that advantage might result from being able to mix some substance with the clay of enamelled ware, which would resist the action of water, as a suitable glaze might then be first employed, and one firing answer for both the biscuit and the gloss, which would save one operation, as well as the time, labour, and expense of fuel.

In *blue-painting*, the colour is mixed with water and gum, and carefully laid on the biscuit ware. As every stroke leaves a mark in the pores of the vessel, great attention must be paid to the pattern, for a stroke once made can never be rubbed out. After the pattern is finished, the ware is allowed to dry by the atmosphere, and is then dipped in the glaze; it is afterwards exposed to heat in the gloss-oven, which fuses the minerals contained in the colours, and gives to each a coating of true gloss: about 4000 young women are employed in this branch of pottery, and by their industry support themselves in a respectable manner.

Blue-printing is the impressions taken from engraved copper-plates by means of a rolling-press. The blue-printer lays the plate upon a stove while the oily colouring substance is rubbed in, and by the heat the metalline particles contained in the oil flow and sink more readily into the engraved lines. The colour is oxide of cobalt, fluxed with different substances, and in suitable proportions, for the pale or dark blues.

The superfluous colour is carefully cleaned off the hot plate, which is laid on the press, and covered with a piece of coarse tissue paper, which has been first brushed over with a strong lie of soft soap, called *sizing*. The whole is now passed through the press, and the heat of the plate dries the paper, renders it more adhesive of colour, and also more easy to be extracted from the plate. The impression when taken off the plate is given to a girl, called a *cutter*, who cuts it into shapes, and hands the parts to a woman, (the *transferrer*,) who puts them on the biscuit, and when she has properly arranged them rubs them till the several pieces are completely affixed to the biscuit article: the article is then left for a short time to imbibe the colouring matter; after which the paper is well washed off with clean water, and the article is put into a kiln to dissipate the oil. Sometimes the outline of a pattern is printed on the ware, and the colours are afterwards added with a pencil.

The earthenware is now ready to receive the smooth coating called *glaze* or *gloss*. The employing of this glaze, though in general, is not always, with a design to prevent the vessel from imbibing the liquid that may, at any future time, be poured into it; because some bodies of earthenware are, before glazed, impermeable to liquids of any kind; but with a design of accomplishing a more important object, that of hiding the substance of the vessel, which is not always either for fineness of texture or whiteness of colour, of a very pre-

possessing appearance. A coating of *mere* glaze would, by its transparency, only expose these defects; even if it were sufficiently contractile and expansile, by sudden changes of temperature, to admit of its being used. Hence is employed a vitrifiable composition of oxides of lead, glass, tin, &c. somewhat resembling common flint-glass, readily made fusible by a little alkali and hardened flint, which will, when well managed, possess sufficient opacity, and by applying a certain degree of heat, flow and vitrify, and render fusible any flint or clay in contact with it, and thus not only fill up the pores of the biscuit article, but cover the whole with an opaque coating, that may be regarded as of real flint-glass.

As the glaze that suits one composition of ware will not suit another, owing to the difference in kinds as well as proportions of materials, it is ever requisite that the components of the glaze be carefully appropriated to the hardness, density, &c. of the components of the clay; because a good glaze should always possess the property of remaining, after being fired, unaffected by heat or cold, in exactly the same ratio as the clay, else on any sudden change of temperature, there would be a counter action between the body and the glaze.

When the article is short-fired, it is always more susceptible of the components of the glassy surface, and becomes altogether crazed, or full of little cracks, which render it permeable to water, and receptive of oily and greasy, and other heterogeneous substances, and ere long the article will, by constant usage, appear very much like a rotten substance.

Crazing is the technical term for the cracking of the glaze, whatever be the cause: whether it arise from excess of alkali in the materials composing the glaze, the deceptive union of the body and glaze, the unsuitableness of the body to the materials of the glaze, the components of the glaze not being equally fusible at the heat employed, or the heat for the proper fusion of the glaze being too high for the body itself.

Mr Parkes states, that a little lime mixed in the clay will prevent crazing; but manufacturers are of opinion that the fact is the contrary. Lime will in a slight degree add to the transparency of porcelain, but ever render it liable to craze. If the articles, whether biscuit or gloss, be taken out of the oven before tolerably cool, the temperature of the air will most generally affect them, and especially the glaze, which is not then properly annealed.

The *glaze* is a vitrifiable composition, about the consistence of, and in appearance, very much like new cream. It is

essential that it be thin, and when fired, possess a degree of opacity to approach as nearly as possible to, and yet be below the fusibility of the biscuit, that the combination may be more intimate and permanent. Hence its composition varies for each body, consonant with the view and experience of the manufacturer; and it is very seldom that it can be applied to another body without previously altering its composition.

In some instances the cost of glazing is much less than in others; though economy is sought for in all, and each manufacturer regards his own as the best and cheapest of the kind for the purpose to which it is employed. Great care is taken that the *recipes*, which are considered very valuable, be kept as much as possible secret among themselves, to prevent foreign potters availing themselves of them, to the injury of our manufacture.

Raw glazes are employed for the common pottery, such as toys, jugs, tea-ware, &c. They are generally composed of white lead, Cornish-stone, and flint, ground by a hand-mill. We have seen a few raw glazes for porcelain of a very good quality; but fritt glazes are mostly used, and are of excellent quality.

Fritt is derived from a certain combination of different materials being well mixed together, or *fritted*, and then calcined; which procures a union of all the parts, and a solidity and purity not otherwise attainable. The fritt is generally placed where it can be affected by a sufficient heat to fuse all its ingredients, without volatilizing the uncombined alkali.

Lynn sand is occasionally one of the ingredients employed in the fritt. Some persons use soda, to render the fritt more fluent while being fired. In some instances, common salt is used along with a portion of potash, which decomposes it, and drives off part of its impurity. The remaining impurities are driven away in the process of fritting. Let it be remembered, however, that brilliancy of glaze is formed only by lead; and that the employment of salts ever produces a poor appearance.

The calcined fritt is pounded, picked, sifted, and ground to an impalpable powder, after which it is mixed with certain proportions of white-lead and flint, and again ground in a very powerful mill. The finer it is ground, the more serviceable it is for the purpose; the glaze is every way better, is more level on the ware, more readily and easily fired, of greater brilliancy, and scarcely ever liable to craze.

The lead causes the other components to vitrify at a certain heat; and accordingly as more or less is used, the glaze

becomes harder or softer. Many objections have been made to its employment: those in referring to vessels for domestic purposes we have already noticed; and in reference to the dippers being subject to paralysis, (which is supposed to result from the lead,) every aid is afforded by preventives, and where attention is paid to personal cleanliness, and the water and towel placed for their use are employed, deleterious effects can seldom be experienced.

The materials being well ground and in a state of fluidity, are next put into the dipping tub. As the materials are heavy it is requisite to keep the powder suspended, and uniformly dispersed through the mass, which weighs about 32 oz. per ale-pint. By the side of this tub stands the dipper, and a boy, his assistant. The boy is employed in brushing the articles, and delivering them, one by one, to the dipper, who dips them quickly into the liquid, and as soon as he takes them out, turns them rapidly about, that the thickness of the liquid may be equal in all the parts. The water is imbibed by the porosity of the biscuit, and there is left a coating of the substances, sufficiently hard to continue affixed until the article be placed in the sagger. The article is then placed on a board, another is similarly dipped, and thus it proceeds until the quantity be finished, when the whole are put into saggers.

When a flat piece has been dipped, it is placed on a board, in which are a number of nails, about an inch above the surface; the superfluous compound runs off, the remainder quickly dries, and soon admits of being moved; which effects a saving in fuel and materials, and the articles are better glazed.

Hollow pieces and blue-printed ware, are placed on hair sieves, or on four pieces of sheet iron, from two to three feet long, called a *fiddle;* in three minutes the dipped articles are sufficiently dry to be removed to the board, and a few minutes afterwards to be placed in the saggers.

In the inferior earthenware certain metallic oxides, as of copper, &c. are mixed with the glaze. These kinds of glazes are distinguished by the name of *dips*. When the article has been thus dipped, it is finished on a turner's lathe, to mark what is to be white, and when the appendages are fixed it is dried in the oven.

The articles are again put into the saggers to fuse the glaze, and as in this process each would attach itself to the other, were they to come in contact, pieces of clay of different sizes and shapes, called stilts, cockspurs, rings, pins, bats, &c. are put to keep them apart.

The saggers are, as before, piled in the *gloss-oven*, which seldom holds more than one-half the quantity of ware fired in the biscuit-oven. The *gloss-fireman* raises the temperature as quickly as possible to a height sufficient to fuse the glaze, which is much lower than the heat of the biscuit-oven, and usually keeps it fired from 16 to 19 hours. *Trials*, made of native red clay, are found very essential in this operation, to prevent the ware being more intensely heated than the biscuit body will bear; for as clay contracts by every addition of heat, were the heat of the gloss-oven to exceed the heat used for the biscuit, the articles would be further contracted, and would be either crooked in shape, or injured in the glaze. The coating of glaze which adhered to the biscuit is, by this firing, uniformly spread over the surface, the particles are fused altogether, and the ware, when cold, appears to be covered with perfect gloss.

As the gloss-oven is sometimes fired to a greater degree of heat than some colours will bear, another process is employed, called *enamelling*, because the designs are more elegant in their execution and form, and the colours are burnt into the glaze of the pottery. These designs are of the finest description, and are most delicately executed upon the glossy surface.

The colours used are generally of a mineral or metallic nature. For *blacks*, oxide of umber and cobalt, and a little oxide of copper. The best oxide of iron is produced by causing heated air to act upon iron.

For *purples* and *violets*, precipitate of cassius, and oxide of gold.

For *greens*, oxide of copper, and precipitate of copper.

And for *blues*, oxide of cobalt.

These oxides are all in an impalpable. powder, and are mixed with a certain powder as a flux, and are so prepared as never to spread beyond their lines, or injure the drawing while being fired.

Each colour is ground with a muller on a large hard stone, and is incorporated with acid of tar, oil of turpentine, or whatever oil may be deemed suitable, and is evaporative. Camel-hair pencils are used to lay the colours on the pottery.

As both males and females are employed in this branch, the men are called *painters*, the women *paintresses*: but in blue-painting, where no men are employed, the women are called *blue-painters*.

This is the finest and most durable species of painting, and it is capable of being employed for the most elegant and valuable embellishments, as neither air, nor wear, can affect

either the beauty of the design, or the brilliancy of the colours.

Gilding requires the precipitate of gold from its solution to be properly mixed with oil of turpentine, and great pains must be taken in laying it on the pieces, which is done in a manner similar to the preceding. When the article is heated, the oxygen flies off and leaves on the ware the gold in a metallic state; but the natural brilliancy of the gold is wanting, consequently, a burnisher of agate, blood-stone, or steel, is applied to the gold, first moistened with flint-water, to procure the bright and shining property of the precious metal, which is, by that means, quickly brought in view. This, when the gold is not too much lowered by fluxing, will scarcely ever tarnish.

Black-printing is a very distinct and curious process. The workman boils a quantity of glue to a certain consistence, and pours it on very smooth dishes, to the thickness of an eighth or a quarter of an inch, according to the size of the plate he may have to use. This, when cold, is cut into sizes for the plate, called *papers*; and he makes as many as he can conveniently use in his routine of working.

Then taking a copper-plate, properly engraved, he rubs into it some well-boiled oil, and having properly cleansed the plate, forcibly presses the glue-paper against it; the latter being firmly fastened to a piece of wood to be held in one hand, and the paper being laid on a boss or cushion held in the other. The oil in the plate adheres by the pressure to the glue-paper, and he carefully, but firmly, presses it and the piece of pottery together; then separates them, and with fine cotton slightly sprinkles the colour, (which is in an impalpable powder,) upon the design left by the oil. After a certain time the oil has evaporated sufficiently to permit all superabundant colour to be wiped off, which is done with much delicacy and attention, by using old silk-rags, and the black printed pottery is placed in the enamel-kiln, where the glaze and colour fuse and incorporate.

The enamel-kiln is commonly made in the shape of a chemist's muffle, from about six to ten feet long, and three to five feet wide; having from one to four mouths, according to the size of the kiln, and the purposes to which it is applied; these mouths are made for the admission of fuel. In this kiln the articles are very carefully placed in layers, or thin bats, until the whole be filled; the mouth is then stopped, and the kiln fired for about eight or ten hours.

The articles, when painted, gilded, or black-printed, are

subjected to a third firing in the enamel-kiln, which fuses both the glaze and the colours, and the mineral or metallic particles flow and become incorporated into the glassy surface.

Lustre ware consists of an inferior quality of the materials worked into the usual forms, and having the hue of gold, platina, or copper, &c. fixed on the glaze, whose great brilliance, when first made, occasioned it to be thus named.

The very easy method of performing the operation, and the quick sale which the articles obtain, has caused it to become so common, and of a quality so inferior, as to be little esteemed by potters.

The pottery to receive lustre is made and glazed for the purpose. That for *gold lustre* is made of the red clay of the district, and when fired gloss, has just a sufficient tint left to give to the articles that peculiar shade of colour observable on viewing them. A very common article of cream-colour is commonly used for the *silver lustre*.

The oxide used for lustre, as gold, platinum, &c. is mixed with some essential oil by the application of heat, and the fluid is brushed over the surface of the articles. Sometimes ornaments are formed on the surface. For this purpose, a thick fluid of soot or lamp-black is laid on the articles, by brushes, according to the patterns, and the articles are then heated in a very hot iron oven, and afterwards have the lustre brushed over them. When dry, they are placed in a kiln, similar to that for enamel ware; which, being carefully fired, dissipates the oxygen, loosens the ornamental article, and restores the metallic lustre to a degree almost equal to its primitive brilliance; but in some cases it is of a coppery and steely brilliance.

In Messrs Rileys' shining black biscuit porcelain, the ware is of a jet black jasper, or porcelain body, having undergone a high degree of vitrification, which elicits a lustre, or bright vitrified polish on the surface, of the appearance of black coral, without a glaze, which is of considerable importance in point of durability, elegance, and usefulness. It is warranted never to change its elegant quality by time or use, and will clean with water, equal to a piece of the finest porcelain. It has a decided advantage over the *dry body*, or *common Egyptian black*, which is generally scoured and oiled to give the surface a smooth appearance, by which it imbibes dust and becomes offensive, and the substance of which it is composed being of a porous nature, it becomes saturated with the liquids poured into it, which eventually prove unwholesome, as well as disagreeable to the hands and sight; the whole of

these disadvantages is obviated by Messrs Rileys' black lustre, which, being perfectly vitrified, allows no liquid to be imbibed.

The direful effects of using lead in the manufacture of pottery are manifest by severe cholics, paralysis of the limbs, and often the untimely death of the workman; and yet this dangerous mineral forms the glaze of the *common red pottery*, in which much of the food of the lower classes is prepared. Lead is slightly soluble in animal oil, more copiously in the acids of our common fruits, and more especially when their action is aided by the heat required in cookery. It is not improbable that many of the visceral disorders of the poor, who use such pottery, are attributable to this little suspected source; and that it is to procure the temporary removal of the pain occasioned by the action of the lead, that they habituate themselves to the deleterious use of distilled spirits.

It was on this view of the subject that the Society for the Encouragement of Arts, Manufactures, and Commerce, were induced to offer their largest honorary premium for the discovery of a glaze for such red pottery, composed of materials not any way prejudicial to the health, and which from its cheapness, and fusibility at the comparatively low temperature required by red pottery, might supersede the use of lead in that branch of manufacture.

This important object was eventually discovered by J. Meigh, Esq. of Shelton, who was well persuaded of the possibility of its accomplishment, and who, without any other stimulus than a desire to benefit mankind, first fully ascertained what particular objects were contemplated by the Society, and then communicated his successful process; by which any makers of red pottery, who may choose to depart from long-established usage, which is but too often the greatest obstacle to improvement, may easily remove the source of the mischief, and considerably improve the quality of the ware, and effect a saving in materials in fuel.

After this view of the subject, we shall not be required to apologize for giving the process in Mr Meigh's own language.

"The common coarse red pottery, being made of brick-clay, is very porous, and is fired at as low a temperature as possible, to save the expense of fuel, and to avoid fusion, or variation of shape, which would result from highly firing common clay; consequently there is needed a glaze to fill up the pores, that the vessel may contain fluids. This glaze must be very fusible, and cheap; hence, for transparent vessels, litharge, and for black opaque, common lead ore, are

used. A glaze of lead, whether altogether or in part, is objectionable, because, first, when quickly raised to the temperature of boiling water, it cracks from different expansibility of the clay and the glaze, so that the liquid permeates the body of the vessel; and secondly, the glass of lead, whether alone or mixed with small proportions of earthy matter, is very soluble in vinegar, in the acid juices of fruits, and in animal fat when boiling."

The injurious effects arising from these have been already stated. Mr Meigh therefore proposes, that a mixture of red marl, which can be easily ground in water to an impalpable paste, and will remain suspended therein for a long time, be employed to dip the vessel in, so that its pores may be filled with the fine particles of the marl, preparatory to glazing; which is performed with a mixture, of the consistence of cream, of equal parts of black manganese, glass, and Cornish-stone, (chiefly felspar,) well ground and mixed together; in a white glaze the manganese is omitted. After undergoing this process, the ware is well dried and fired, as usual.

Mr Meigh also proposes a substitute for the materials of the common red pottery, consisting of four parts common marl, one part red marl, and one part brick-clay. The ware made in this way is of a reddish cream-brown, harder, more compact, and less porous, than the red pottery; more economical to the potter, and calculated to contribute in no inconsiderable degree to the health of the lower classes who use the red pottery.

The aim of the principal manufacturers has been to obtain the composition of a clay and glaze for porcelain, which, when fired, should be very fine in its texture, extremely white in colour, possess considerable transparency, and at the same time be able to bear different degrees of heat and cold. That the reader may understand more fully the several peculiarities which are considered by manufacturers as essential to perfect porcelain, we shall state,

That the first and most important quality is a superiority in the *whiteness* of the porcelain; that its appearance be free from any specks, and that it be covered with a rich and very white glaze of almost velvet softness in appearance, and of best flint-glass smoothness to the touch.

That the second important and essential quality is *durability*, or a substance whose components will bear, without being injuriously affected, a sudden and rapid increase of temperature, and particularly to sustain unaltered, the action of boiling water.

That the third essential quality is *transparency*, which is admitted to be, in some measure, requisite, but certainly not entitled to that high degree of preference so frequently given to it, the best porcelain being a shade less transparent than a kind much inferior.

Formerly, connoisseurs very highly estimated porcelain of a fine granular texture; but this criterion of excellence cannot always be relied on.

To ascertain the texture of an article, it must be fractured, and thereby tacitly destroyed; the semi-vitrification and closeness of texture observable in one piece will not be so obvious, but there will be a varied appearance in different pieces, though all be fabricated at the same time, and from the same mass of materials.

Stone-china is formed of a compound of Cornish-stone and clay, blue clay, and flint; and with a glaze, consisting of lead, bullet-glass, Cornish-stone, and flint. It is very dense and durable, but less transparent than bone-china; and is very much used for jugs, and the larger sorts of vessels.

Iron-stone china is not very transparent; but possesses great strength, compactness, density, and durability. It is not much used for tea-ware, but has very suitable properties for dinner and supper services, jugs, and ornaments. It was discovered by Messrs G. and C. Mason, and has been more productive than any other species of pottery or porcelain.

Felspar china, which has been only very recently introduced, is the most noted of all the porcelains; it results from the introduction of certain proportions of a fresh material into both the clay and glaze.

Cornish-stone is a species of granite in a state of decomposition, and contains much felspar. *Cornish-clay* is found in situations where this decomposition is in progress. The decomposing granite is broken up with pick-axes, and the fragments are thrown into running water, whose action washes off, and keeps in suspension, the slight argillaceous particles miscible with that fluid. The water is discharged into pans or pits, where the particles subside, and the water is evaporated, formerly by the atmosphere, but now by heated flues passing under the reservoirs. When the water is evaporated, the substance is cut out in square lumps, and placed on shelves to dry, when it becomes extremely white, and in the state of an impalpable powder. It is then packed up in casks, and forwarded to the manufacturers.

The *clay* of the best felspar porcelain is formed of certain

proportions of china-stone and felspar; the mixing of the proportions requires much attention, for an excess of felspar would cause the vessels to shrink in the biscuit-oven, prior to the fusion of the clayey particles, which causes its transparency; and an excess of china-clay would increase the opaqueness. In both cases, the glaze would expand and contract in a ratio differing from that of the biscuit, and cause the pieces to be crazed. The fusibility of native felspar is owing to its containing about 13 per cent. of potash, which causes it to be one of the best materials for glazing porcelain. Calcined bone is used, and renders the clay very white; but it should be employed with judgment, as its great contractibility causes the articles wherein it is used to excess, to crack on sudden changes of temperature.

Beside the porcelain or china-clay already noticed, the manufacturers use *four* other kinds; the two first from Devonshire, the two last from Dorsetshire.

The *black-clay* is remarkable for the fact, that the bituminous matter which gives the colour whence it derives its name, flies off by firing; and the blacker the clay when first dug, the whiter will be the pottery.

The *cracking-clay* is used because of its extremely beautiful whiteness when fired; but it requires very exact proportions of flint, otherwise the ware will crack during the firing of the biscuit.

The *brown-clay* burns very white without cracking, and some manufacturers use much of it; but as the ware does not so readily imbibe the particles of melting glaze, the liability of the ware to craze causes others to reject it altogether. This clay is with difficulty sifted through the lawn, requires much longer *weathering*, or exposure to the action of the atmosphere, for the separation of its particles, and to prevent crazing, different proportions of other materials; but the greatest objection to it is, that some of the kind sent within these few years has always burned inferior in colour to what it formerly did.

The *blue-clay* is the best, and the most expensive. It forms a very white and solid body, and requires a much greater proportion of flint, which considerably improves the quality of the ware; but the proportions require very strict attention, and a higher degree of biscuit-fire.

The *cream-coloured pottery* has its name from the tint of its colour, being that of new cream. It is, when well made, and properly fired, very sonorous, sufficiently hard to elicit sparks by the application of steel, and will contain liquids without being permeated by them. When it is of good quality it will resist the action of nitre, glass of lead, and other fluxes, which renders it of great utility in all domestic and chemical processes where great heat is used. Care must be paid to the current of air while the pottery is in contact with fire, otherwise its hardness and density, by preventing its sudden contraction or expansion, renders it very liable to break.

Wedgwood's cream-coloured pottery is allowed to retain

its superiority, neither failing nor crazing through age; while much of the pottery made by persons of small capital is very subject to both these defects.

Cream colour is formed, according to the views of the manufacturers, of various proportions of blue and porcelain clays, flint and Cornish-stone; others add black, or brown, and cracking clays, with little flint and stone. Recent experiments prove that pottery of very good quality may be made by mixing from 30 to 40 per cent. of the native clay with blue and porcelain clays, and flint and stone.

The glaze for cream-coloured pottery is formed of white lead, Cornish-stone, and flint. The excess of lead renders the glaze more or less yellow, which is remedied by the application of other materials; the flint gives consistence to the lead during vitrification, and prevents its great fluidity, which else would cause it to run down the sides of the ware, and leave certain parts without glaze.

The deleterious effects arising from the employ of white-lead in the fabrication of vessels used for condiments have been pointed out, as has also the importance of a substitute; but as the best manufacturers use much Cornish-stone and flint in their glaze, and most especially for those vessels called bakers, the cause of complaint does not attach itself to their pottery. All persons, therefore, who wish their pickles and preserves to be unaffected by this poisonous mineral, should resolve on purchasing their jars from the dealers who have their goods from the most respectable manufacturers, who will readily vouch for the excellence of their articles.

It is not sufficiently known, that most of the earthenware sold by hawkers, or pedlars, is of a very inferior and dangerous quality. The components of the clay of which this common earthenware is made, will not bear a fair degree of heat, and in addition to the ware being short-fired in the biscuit, the glaze is too soft and short-fired; hence, when such earthenware has been used a few times, the hot water requisite for cleansing it will cause all its defects to be obvious, and ere long it becomes so crazed as to resemble a rotten substance.

This soft and soft-glazed pottery is easily scratched by a knife; oily matters standing on it will stain and render it dull; and vinegar, and other weak acids, will attack and dissolve the lead.

The proper cream colour will bear all of these uninjured, and so small a quantity of lead is used, that, when properly glazed, pernicious effects need not be apprehended.

It is the opinion of some very intelligent potters, that the

total rejection of lead is not compatible with perfection in pottery.

The *blue-printed pottery* is a very popular kind, and most persons who have seen it placed near the preceding, must have remarked that it is of a finer kind, with a very different tint or colour.

The best species is in considerable demand for dinner, dessert, tea, and supper services; while its cheapness has caused it to supersede almost every kind of ware.

The difference is caused by two peculiarities; one in the clay, arising from the employment of a greater proportion of blue and porcelain clays and flints; the other in the glaze, from certain components being mixed together, and calcined into a frit, which is often picked and sifted, then ground together with glass and white-lead, and mixed with certain proportions of Cornish-stone and flint.

One kind of this pottery has its glaze varied to capacitate it for enamelling. The blue printed tea-ware has recently obtained the name of *semi-china*, owing to its being, when well fired, very fine, white and neat, and possessing some degree of transparency.

The *chalky pottery* is a very excellent and beautiful kind, having a delicate white appearance, of fine texture, and glassy smoothness. The nature of the clay and the glaze renders it very proper for enamelling, as smalts are introduced, in accordance with the views of the maker, to effect the tints.

The clay is boiled on a plaster-kiln, and consists of certain proportions of porcelain, blue and Welsh clays, pulverized, calcined, or raw flints, Cornish-stone, white enamel, tinged with smalts; and some persons add calcined bone and plaster of Paris. This ware requires a most ardent fire for the biscuit.

The glaze is composed of a frit of glass, Cornish-stone, flint, borax, nitre, red-lead, potash, Lynn sand, soda, and cobalt calx. After fritting, and being well fired, it is ground and mixed together with white-lead, glass, flint, and Cornish-stone.

The *fine red pottery* is formed of almost equal proportions of yellow brick-clay and the red from Bradwall-wood; an inferior sort is made for lustre-ware.

In the Hall-field colliery, east side of Henley, is found a marl, which, when properly prepared, by levigating and drying, will alone from a very beautiful light red, of four distinct shades, according to the intensity of the firing. This was discovered by Mr G. Jones, in 1814, who commenced a manufacture of this kind of ornamental pottery for Messrs Burnett,

to be shipped to Holland; but the sudden return of Napoleon from Elba so disconcerted the arrangements, that the elder Mr Burnett died suddenly, and Jones did not long survive the disappointment he experienced.

The introduction of ochre will change the red to a brown colour.

The *bamboo, or cane-coloured pottery*, is a very beautiful kind, employed chiefly for ornamental articles, and the larger vessels of tea-services. It is never glazed outside, though one kind has the outside vitrified. The insides of tea-ware are well washed with a liquid which forms, when fired, a thin coating of glass. The colour varies from that of a light bamboo to almost a buff: but the prevalent colour is nankeen. The best clay or body is formed of proportions of black marl, brown clay, Cornish-stone, and shavings of cream-coloured pottery.

The *jasper pottery* was invented by Mr J. Wedgwood. It is extremely beautiful; and is formed of blue and porcelain clay, Cornish-stone, Cork-stone, (sulphate of barytes,) flint, and a little gypsum, tinged with cobalt calx.

The *pearl pottery* is a superb kind for elegant and tasteful ornaments, and is so much valued, that the workmen are usually locked up, and employed only on choice articles. The components of the clay are blue and porcelain clay, Cornish-stone, a little glass, and red-lead. This forms the best body for apothecaries' mortars; but it is more expensive, and more durable, than the common mortar body.

The *black Egyptian pottery* is now so very popular for tea-services, that few persons are ignorant of what is meant by this denomination. Its components are cream-coloured slip, manganese, and ochre; sometimes glazed with lead, Cornish-stone, and flint; and the inside is washed with white-lead, flint, and manganese. It was the custom formerly to grease the outside with butter or suet, to give it a bright appearance.

The ochreous material is obtained from the water that is pumped out of the collieries. This water is carried along channels in which are placed small weirs, to afford an opportunity for the precipitation of the sediment. When a sufficient quantity has accumulated, the water is diverted, the weirs are emptied, and the thick fluid is thrown into small pools, called sun-pans, whence the moisture is evaporated by the solar heat. This substance is afterwards burned with small-coal, which renders it proper for use.

The unpleasantness of the grease, requisite to give brightness to the black, having been a subject of general complaint,

Messrs Riley of Burslem, were induced to attempt to remedy it; the result of which was, the invention of a new black porcelain, with a bright burnished, vitrescent appearance, superior to any other kind of dry-body pottery. It never imbibes dust, or absorbs moisture; and it can be cleaned with water equally as well as the finest porcelain, and always retains the appearance of a beautiful black coral.

The *drab pottery* is useful for articles which require strength to be united to ornament, as flower-pots, water-jugs, &c. It is formed of blue, porcelain, and Bradwall-wood clays, Cornish-stone, and black marl, mixed with nickel; one kind is made of turners' shavings of cream-coloured ware made into slip, and mixed with nickel. The inside is rendered white by a wash of slip, flint, and porcelain clay.

It has for some time been usual for ladies of taste and acquirements in the fine arts to purchase porcelain in its glazed state, for the exercise of their talents and ingenuity in ornamenting their own tea-services. This very pleasing amusement is often aided by manufacturers, who readily afford every assistance in their power to facilitate the easy enamelling of such services; they supply proper mineral colours, and the rectified oil of amber, for the best purposes, and the best oil of turpentine for others; and they attend to the proper firing of the enamel, burnish the gold, and dress off the whole for the table.

The different combinations of materials appear to be of less importance in the fabrication of good pottery, than due regard to well-determined proportions. All clays have some proportions, more or less, of metallic matter, which cause great difference in their appearance, and the effects produced on them by fire. All clays vary in colouring according to the ardency of the fire; hence the oven-man's greatest care is, to place the saggers in the most appropriate parts.

The chief ingredients are clay and flint; for no pottery will be perfect unless made of suitable clay, with a definite proportion of flint. The great difficulty is to unite beauty and goodness in the same composition. If too much flint be used, the pottery, after being fired, will crack on exposure to the air; and if too little, the glaze will not be retained on it after firing. Every kind of clay that is dried alone will crack; for if pure argillaceous earth be made sufficiently soft to be wrought on the potter's wheel, it will, while drying, shrink one inch in twelve, which will inevitably cause it to craze.

Pure clay (*alumina*,) is always opaque, and the flint (*silica*,) always transparent; but both are prepared previously to

being used. Alumina will unite with silica in the humid way, and form a paste, which, when dry, will resist decomposition by atmospheric affection.

Experienced manufacturers know that they can easily compound clays which will fire very white, be beautifully semi-transparent for porcelain, and bear to be covered with a shining glaze; but they will prove deficient in tenacity for working, want proper compactness and density, break by sudden applications of heat and cold, and the glaze, because too soft, will crack, become rough, and lose its lustre. Again, they compound clays which have suitable tenacity for working, become very hard and dense without fusing by being fired, sustain, uninjured, sudden changes of excess of temperature, and are yet deficient in the requisite whiteness, fineness of texture, beauty, and transparency. Some clays of this description are manufactured.

Having proceeded thus far, the reader may feel surprised that we have not accompanied our observations with recipes for the manufacture of the several kinds of pottery, as is customary in works of this description; but these, we can assure him, are, as far as we have seen, erroneous; and, indeed, the manufacturers are so very silent upon this head, that the exact proportions of the components of bodies, glazes, and colours, cannot easily be obtained. We shall therefore conclude this article by stating, that the district called "the Potteries," is an extensive tract of country in the hundred of North Pyrehill and county of Stafford, comprehending an area of about eight miles long, and six broad; and that the principal towns and hamlets contained within the limits of the Pottery are Stoke, Henley, Shelton, Golden-hill, Newfield, Smith-field, Tunstall, Long-port, Burslem, Cobridge, Etruria, Lune-End, Lower Lune, and Lune-Delft.

HOROLOGY.

In the early ages, time was measured either by the sun-dial or clepsydra; in the former, by the shadow of a wire, or of the upper edge of a plane, erected perpendicularly on the dial, falling upon certain lines meant to indicate the hour; in the latter, by the escape of water from a vessel through a small orifice, which vessel had certain marks upon it to show the time the vessel was discharging.

These modes are now superseded by the use of clocks, watches, and chronometers, which indicate time by the movement of machinery.

Under this general head of Horology, therefore, we propose to treat of the structure of the several kinds of machines now used for the exact measurement of time; in doing which, the articles will of necessity be divided into three sub-heads, Clocks, Watches, and Chronometers; and to them will be annexed two others, treating of some of the best kinds of pendulums and escapements.

CLOCKS.

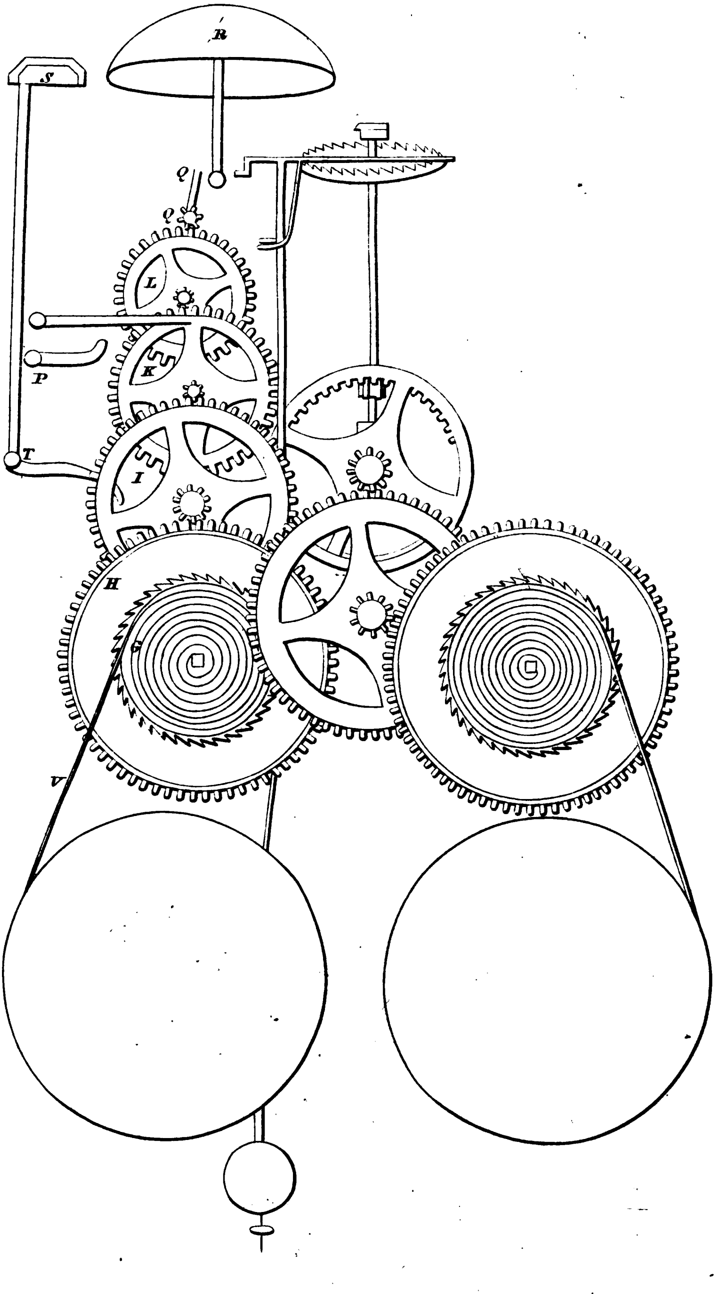
Clocks are certain machines, constructed in such a manner, and so regulated by the uniform action of a pendulum, as to measure time, in larger or smaller portions, with great exactness.

Fig. 489 represents the profile of a clock. P is a weight suspended by a rope that winds about the cylinder or barrel C, which is fixed upon the axis *a a*; the pivots *b b* go into holes made in the plates T S, T S, in which they turn freely. These plates are made of brass or iron, and are connected by means of four pillars Z Z, and the whole together is called the frame.

The weight P, if not restrained, would necessarily turn the barrel C with an uniformly accelerated motion, in the same manner as if the weight were falling freely from a height; but the barrel is furnished with a ratchet-wheel K K, the right sides of whose teeth strike against the click, which is fixed with a screw to the wheel D D, as represented in fig. 490, so that the action of the weight is communicated to the wheel D D, the teeth of which act upon the teeth of the small wheel *d*, which turns upon the pivots *c c*. The communication or action of one wheel with another is called the *pitching;* a small wheel like *d* is called a *pinion*, and its teeth the *leaves* of the pinion. Several things are requisite to form a good pitching, the advantages of which are obvious in all machinery where teeth and pinions are employed. The teeth and pinion-leaves should be of a proper shape, and perfectly equal among themselves; the size also of the pinion should be of a just proportion to the wheel acting upon it; and its place must be at a certain distance from the wheel, beyond or within which it will make a bad pitching.

The wheel E E is fixed upon the axis of the pinion *d;* and the motion communicated to the wheel D D by the weight is transmitted to the pinion

491 p 51.



d, consequently to the wheel E E, as likewise to the pinion *e*, and wheel F F, which moves the pinion *f*, upon the axis of which the crown or balance-wheel G H is fixed. The pivots of the pinion *f* play in holes of the plates L M, which are fixed horizontally to the plates T S. In short, the motion begun by the weight is transmitted from the wheel G H to the pallets I K, and by means of the fork U X, rivetted on the pallets, communicates motion to the pendulum A B, which is suspended upon the hook A. The pendulum A B describes, round the point A, an arc of a circle, alternately going and returning; if, therefore, the pendulum be once put in motion by a push of the hand, the weight at B will make it return upon itself, and it will continue to go alternately backward and forward till the resistance of the air upon the pendulum, and the friction at the point of suspension at A, destroys the originally impressed force. But as, at every vibration of the pendulum, the teeth of the balance-wheel G H act so upon the pallets I K, (the pivots upon the axis of these pallets play in two holes of the potence *s t*,) that after one tooth, H, has communicated motion to the pallet K, that tooth escapes, then the opposite tooth, G, acts upon the pallet I, and escapes in the same manner; and thus each tooth of the wheel escapes the pallets I K, after having communicated their motion to the pallets in such a manner that the pendulum, instead of being stopped, continues to move.

The wheel E E revolves in an hour. The pivot *c* of the wheel passes through the plates, and is continued to *r*; upon the pivot is a wheel N N, with a long socket fastened in the centre; upon the extremity of this socket, *r*, the minute-hand is fixed. The wheel N N acts upon the wheel O, the pinion, *p*, of which acts upon the wheel *g g*, fixed upon a socket which turns along with the wheel R. The wheel *g g* makes its revolutions in twelve hours, upon the socket of which the hour-hand is fixed.

From the foregoing description it is evident, first, that the weight P turns all the wheels, and at the same time continues the motion of the pendulum; secondly, that the quickness of the motion of the wheels is determined by that of the pendulum; and thirdly, that the wheels point out the parts of time divided by the uniform motion of the pendulum.

When the cord from which the weight is suspended is entirely run down from off the barrel, it is wound up again by means of a key, which goes on the square end of the arbor at Q, by turning it in a contrary direction from that in which the weight descends. For this purpose, the inclined side of the teeth of the wheel R, fig. 490, removes the click C, so that the ratchet-wheel, K, turns while the wheel D is at rest; but as soon as the cord is wound up, the click falls in between the teeth of the wheel D, and the right side of the teeth again act upon the end of the click, which obliges the wheel D to turn along with the barrel, and the spring A keeps the click between the teeth of the ratchet-wheel R.

We shall now explain how time is measured by the pendulum; and how the wheel E, upon the axis of which the minute-hand is fixed, makes but one precise revolution in an hour. The vibrations of a pendulum are performed in a shorter or longer time in proportion to the length of the pen-

dulum itself. A pendulum of 3 feet 8½ French lines in length makes 3,600 vibrations in an hour, that is, each vibration is performed in a second of time, and for that reason it is called a *seconds pendulum;* but a pendulum of 9 inches 2¼ French lines makes 7,200 vibrations in an hour, or two vibrations in a second of time, and is called a *half-second pendulum.* Hence, in constructing a wheel whose revolution must be performed in a given time, the time of the vibrations of the pendulum, which regulates its motion, must be considered. Supposing, then, that the pendulum A B makes 7,200 vibrations in an hour, let us consider how the wheel E shall take up an hour in making one revolution. This entirely depends on the number of teeth in the wheels and pinions. If the balance-wheel consists of 30 teeth, it will turn once in the time that the pendulum makes 60 vibrations; for at every turn of the wheel, the same tooth acts once on the pallet I, and once on the pallet K, which occasions two separate vibrations in the pendulum; and the wheel having 30 teeth, it occasions twice 30 or 60 vibrations. Consequently, this wheel must perform 120 revolutions in an hour, because 60 vibrations, which it occasions at every revolution, are contained 120 times in 7,200, the number of vibrations performed by the pendulum in an hour.

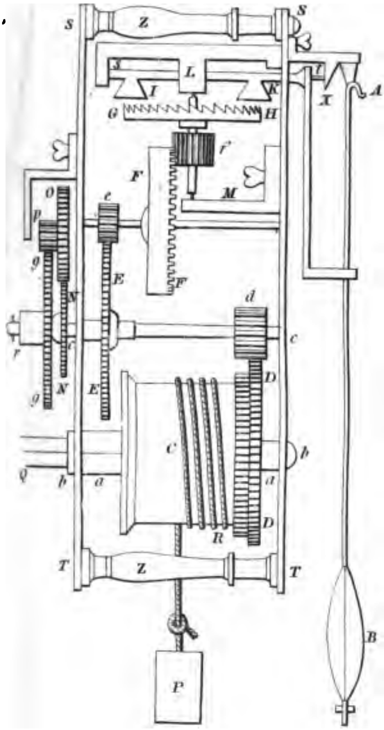
In order to determine the number of teeth for the wheels E F, and the pinions *e f*, it must be remarked, that one revolution of the wheel E must turn the pinion *e* as many times as the number of teeth in the pinions is contained in the number of teeth in the wheel. Thus, if the wheel E contains 72 teeth, and the pinion *e* six, the pinion will make twelve revolutions in the time that the wheel makes one; for each tooth of the wheel drives forward a tooth of the pinion, and when the six teeth of the pinion are moved, a complete revolution is performed, but the wheel E has by that time only advanced 6 teeth, and has still 66 to advance before its revolution be completed, which will occasion 11 more revolutions of the pinion. For the same reason the wheel F having 60 teeth, and the pinion *f* six, the pinion will make ten revolutions while the wheel performs one. Now the wheel F, being turned by the pinion *e*, makes 12 revolutions for one of the wheel E, and the pinion *f* makes 10 revolutions for one of the wheel F; consequently the pinion *f* performs 10 times 12, or 120 revolutions, in the time the wheel E performs one. But the wheel G, which is turned by the pinion *f*, occasions 60 vibrations in the pendulum each time it turns round; consequently, the wheel G occasions 60 times 120, or 7,200 vibrations of the pendulum, while the wheel performs one revolution; but 7,200 is the number of vibrations made by the pendulum in an hour, and consequently the wheel E performs but one revolution in an hour; and so of the rest.

From this reasoning, it is easy to discover how long a clock may be made to go for any length of time without winding up: 1. By increasing the number of teeth in the wheels; 2. By diminishing the number of teeth in the pinions; 3. By increasing the length of cord that suspends the weight;

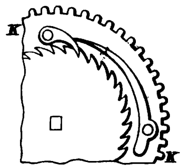
CLOCKS.

From 490 to 495

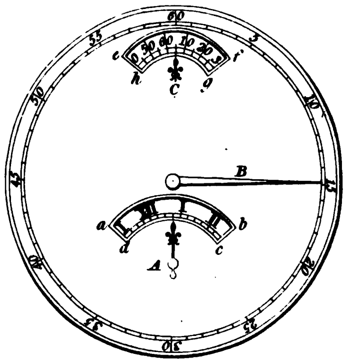
489 p 48.



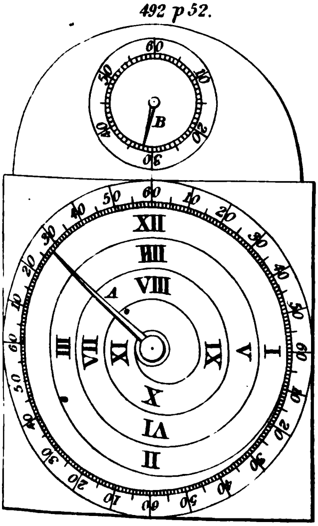
490 p 49.



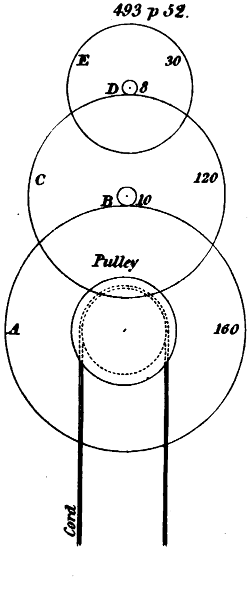
494 p 52.



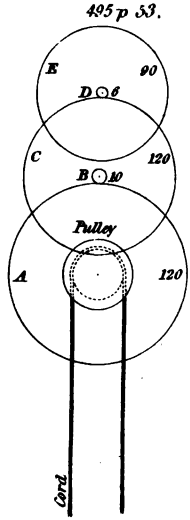
492 p 52.



493 p 52.



495 p 53.



4. By increasing the length of the pendulum; and 5. By adding to the number of the wheels and pinions. But, in proportion as the time is augmented, if the weight continues the same, the force which it communicates to the last wheel, G H, will be diminished.

It only now remains for us to take notice of the number of teeth in the wheels which turn the hour and minute-hands. The wheel E performs one revolution in an hour; the wheel N N, which is turned by the axis of the wheel E, must likewise make only one revolution in the same time; and the minute-hand is fixed to the socket of this wheel. The wheel N has 30 teeth, and acts upon the wheel O, which has likewise 30 teeth, and the same diameter; consequently the wheel O takes one hour to a revolution. Now the wheel O carries the pinion *p*, which has six teeth, and which acts upon the wheel *g g*, of 72 teeth; consequently the pinion *p* makes 12 revolutions while the wheel *g g* makes one, and of course the wheel *g g* takes 12 hours to one revolution; and upon the socket of this wheel the hour-hand is fixed. All that has been here stated concerning revolutions is equally applicable to watches as to clocks.

Clock-work, properly so called, is that part of the movement which strikes the hours, &c. on a bell; in contradistinction to that part of the movement of a clock or watch which is designed to measure and exhibit the time on a dial-plate, and which is termed *watch-work*.

Fig. 491 represents the clock part. H is the first or great wheel, moved by means of the weight or spring at the barrel G. In 16 or 34 hour clocks, this wheel has usually pins, and is called the *pin-wheel;* and in eight-day pieces, the second wheel, I, is commonly the pin-wheel, or striking-wheel, and is moved by the former. Next the striking-wheel is the detent-wheel, or hoop-wheel, K, having a hoop almost round it, wherein is a vacancy at which the clock locks. The next is the third or fourth wheel, according to its distance from the first, called the *warning-wheel,* L. The last is the flying-pinion, Q, with a fly or fan, to gather air, and so bridle the rapidity of the clock's motion. To these must be added the pinion of report, which drives round the locking-wheel, called also the *count-wheel,* which has, in general, eleven notches placed at unequal distances, to make the clock strike the hours.

Besides the wheels, to the clock part belongs the rash or ratch, which is a kind of wheel with twelve large fangs, running concentrical to the dial-wheel, and serving to lift up the detents every hour, and make the clock strike; the detents, or stops, which being lifted up and let fall, lock and unlock the clock in striking; the hammer, as S, which strikes the bell R; the hammer-tails, as T, by which the striking-pins draw back the hammers; latches, whereby the work is lifted up and unlocked; and lifting-pieces, as P, which lift up and unlock the detents.

We shall now proceed to give a description of an ingenious

clock, contrived by the late Dr. Franklin, of Philadelphia, that showed the hours, minutes, and seconds, with only three wheels and two pinions in the whole movement.

The dial-plate of this clock is represented by fig. 492. The hours are engraved in spiral places, along two diameters of a circle, containing four times 60 minutes. The index A goes round in four hours, and counts the minutes from any hour it has passed by to the next following hours. The time as appears in the figure is either 32½ minutes past 12, or past 4, or past 8; and so on in each quarter of the circle, pointing to the number of minutes after the hours the index has left in its motion. Now, as one can hardly be four hours mistaken in estimating the time, he can always tell the true hour and minute by looking at the clock, from the time he rises till the time he goes to bed. The small hand B, in the arch at top, goes round once in a minute, and shows the seconds as in a common clock.

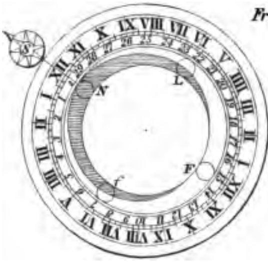
Fig. 493 shows the wheel-work of the clock. A is the first or great wheel; it contains 160 teeth, goes round in four hours, and the index A, (fig. 492,) is put upon its axis, and moved round in the same time. The hole in the index is round; it is put tight upon the round end of the axis, so as to be carried by the motion of the wheel, but may be set at any time to the proper hour and minute, without affecting either the wheel or its axis. This wheel of 160 teeth turns a pinion, B, of ten leaves; and as 10 is but a sixteenth part of 160, the pinion goes round in a quarter of an hour. On the axis of this pinion is the wheel C of 120 teeth; it also goes round in a quarter of an hour, and turns a pinion D, of eight leaves, round in a minute; for there are 15 minutes in a quarter of an hour, and 8 times 15 is 120. On the axis of this pinion is the second-hand B, (fig. 492,) and also the common wheel E, fig. 493, of 30 teeth, for moving a pendulum, (by pallets,) that vibrates seconds, as in a common clock.

This clock is not designed to be wound up by a winch, but to be drawn up like a clock that goes only thirty hours. For this purpose, the line must go over a pulley on the axis of the great wheel, as in a common thirty-hour clock.

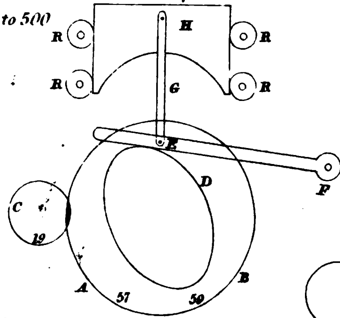
One inconvenience attending this clock is, that if a person wake in the night, and look at the clock, he may possibly be mistaken in the four hours, in reckoning the time by it, as the hand cannot be upon any hour, or pass by any hour, without being upon, or passing by, four hours at the same time. In order, therefore, to avoid this inconvenience, the ingenious Mr. Ferguson contrived the following method.

In fig. 494, the dial-plate of such a clock is represented; in which there is an opening, *a b c d*, below the centre. Through this opening, part of a flat plate appears, on which the 12 hours are engraved, and divided into quarters. This plate is contiguous to the back of the dial-plate, and turns round in twelve hours; so that the true hour or part thereof, appears in the middle of the opening, at the point of an index, A, which is engraved on the face of the dial-plate. B is the minute-hand as in a common clock, going round through all the 60 minutes on the dial in an hour; and in that time the plate seen through the opening *a b c d* shifts one hour under the fixt, engraven index A. By these means the hour and minute may be always known at whatever time the dial-plate is viewed. In this plate is another opening, *e f g h*, through which the seconds are seen on a flat

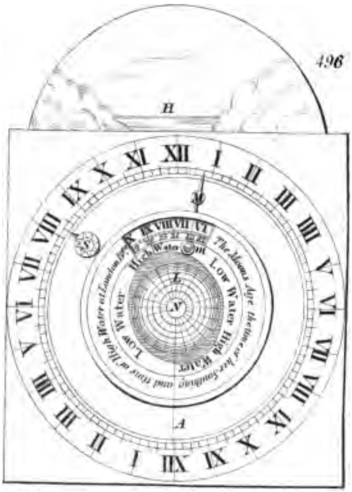
497 p 55



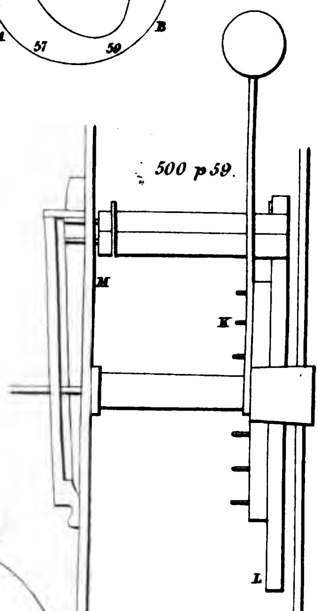
498 p 55.



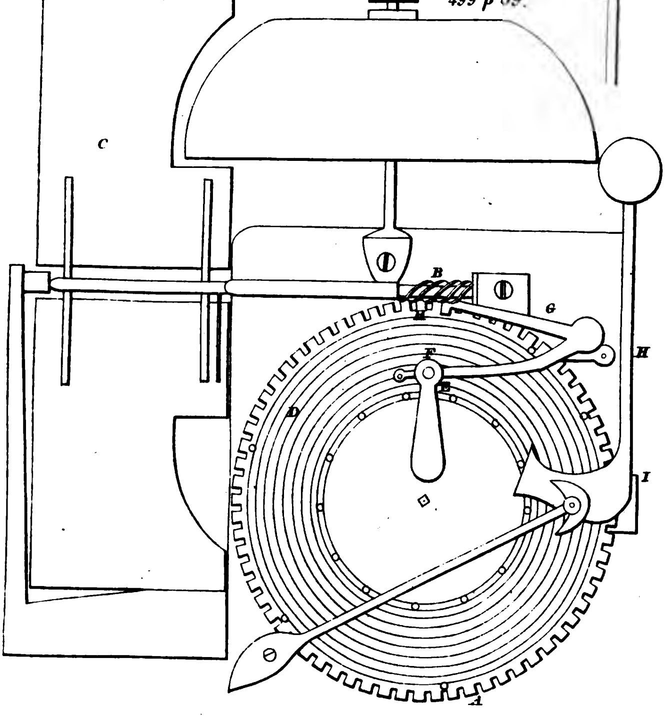
496 p 54.



500 p 59.



499 p 59.



movable ring, almost contiguous to the back of the dial-plate, and as the ring turns round, the seconds upon it are shown by the top point of a fleur-de-lis C, engraved on the face of the dial-plate.

Fig. 495 represents the wheels and pinions in this clock. A is the first or great wheel; it contains 120 teeth, and turns round in 12 hours. On its axis is the plate on which the 12 hours above-mentioned are engraved. This plate is not fixed on the axis, but is only put tight upon a round part thereof, so that any hour, or part of an hour, may be set to the top of the fixed index A, fig. 494, without affecting the motion of the wheel. For this purpose, twelve small holes are drilled through the plate, one at each hour, among the quarter divisions: and by putting a pin into any hole in view, the plate may be set, without affecting any part of the wheel-work. This great wheel A, of 120 teeth, turns a pinion B, of ten leaves, round in an hour; and the minute-hand B, fig. 494, is on the axis of this pinion, the end of the axis not being square but round, that the minute-hand may be turned occasionally upon it without affecting any part of the movement. On the axis of the pinion B is a wheel C of 120 teeth, turning round in an hour, and turning a pinion D, of six leaves, in three minutes; for three minutes is a twentieth part of an hour, and 6 is a twentieth part of 120. On the axis of this pinion is a wheel E of 90 teeth, going round in three minutes, and keeping a pendulum in motion that vibrates seconds, by pallets, as in a common clock, where the pendulum-wheel has only 30 teeth, and goes round in a minute. But as this wheel goes round only in three minutes, if it be wanted to show the seconds, a thin plate must be divided into 3 times 60, or 180 equal parts, and numbered 10, 20, 30, 40, 50, 60; 10, 20, 30, 40, 50, 60; 10, 20, 30, 40, 50, 60; and fixed upon the same axis with the wheel of 90 teeth, so near the back of the dial-plate, as only to turn round without touching it: and these divisions will show the seconds through the opening *efgh* in the dial-plate, as they slide gradually round below the point of the fixed fleur-de-lis C.

As the great wheel A, and pulley on its axis, over which the cord goes, (as in a common thirty-hour clock,) turns round only once in twenty-four hours, this clock will go a week with a cord of common length, and always have the true hour, or part of that hour, in sight at the upper end of the fixed index A on the dial-plate.

There are two advantages which Mr. Ferguson's clock has beyond Dr. Franklin's: but it has two disadvantages of which his clock is free. For in this, although the twelve-hour wheel turns the minute index B, yet if that index be turned by hand to set it to the proper minute for any time, it will not move the twelve-hour plate to set the corresponding part of the hour even with the top of the index A: and therefore, after having set the minute index B right by hand, the hour-plate must be set right by means of a pin put into the small hole in the plate just below the hour. It is true there is no great disadvantage in this; but the pendulum-wheel having ninety teeth instead of the common number thirty, may probably make some difference to the scapement, on account of the smallness of the teeth; and it is certain that it will cause the pendulum-ball to describe but small arcs in its vibrations.

Some men of science think small arcs are best; but wherefore we know not. For whether the ball describes a large or a small arc, if the arc be nearly cycloidal, the vibrations will be performed in equal times; the time therefore will depend entirely on the length of the pendulum-rod, not on the length of the arc the ball describes. The larger the arc is, the greater the momentum of the ball; and the greater the momentum is, the less will the time of the vibrations be affected by any unequal impulse of the pendulum-wheel upon the pallets.

The greatest objection to Mr. Ferguson's clock is, that the weight of the flat ring on which the seconds are engraved, will load the pivots of the axis of the pendulum-wheel with a great deal of friction, which ought by all possible means to be avoided; and yet one of these clocks, recently made, goes very well, notwithstanding the weight of this ring. This objection, however, can easily be remedied by leaving it out; for seconds are of very little use in common clocks not made for astronomical observations; and table clocks never have them.

Having thus described this clock, we shall next proceed to give a description of a clock, by the same ingenious mechanic, for showing the apparent daily motions of the sun and moon, the age and phases of the moon, with the time of her coming to the meridian, and the times of high and low water, by having only two wheels and a pinion added to the common movement.

Mr. Ferguson's clock for exhibiting the apparent daily motions of the sun and moon, and state of the tides, &c.

The dial-plate of this clock is represented by fig. 496. It contains all the twenty-four hours of the day and night. S is the sun, which serves as an hour index, by going round the dial-plate in twenty-four hours; and M is the moon, which goes round in twenty-four hours fifty minutes and a half, from any point in the hour circle to the same point again, which is equal to the time of the moon's going round in the heavens, from the meridian of any place to the same meridian again. The sun is fixed to a circular plate, as fig. 497, and carried round by the motion of the plate, on which the twenty-four hours are engraven, and within them is a circle divided into twenty-nine and a half equal parts for the days of the moon's age, accounted from the time of any new moon to the next after; and each day stands directly under the time, (in the twenty-four hour circle,) of the moon's coming to the meridian, the twelve under the sun standing for mid-day, and the opposite twelve for mid-night. Thus, when the moon is eight days old, she comes to the meridian at half an hour past six in the afternoon; and when she is sixteen days old, she comes to the meridian at one o'clock in the morning. The moon M, fig. 496, is fixed to another circular plate, of the same diameter with that which carries the sun; and

this moon-plate turns round in twenty-four hours fifty minutes and a half. It is cut open, so as to show some of the hours and days of the moon's age; on the plate below it that carries the sun, and across this opening at *a* and *b* are two short pieces of small wire in the moon-plate. The wire *a* shows the day of the moon's age, and time of her coming to the meridian, on the plate below it that carries the sun: and the wire *b* shows the time of high water for that day, on the same plate. These wires must be placed as far from one another, as the time of the moon's coming to the meridian differs from the time of high water at the place where the clock is intended to serve. At London-bridge it is high water when the moon is two hours and a half past the meridian.

Above this plate that carries the moon, there is a fixed plate N, supported by a wire A, the upper end of which is fixed to that plate, and the lower end is bent to a right angle, and fixed into the dial-plate at the lowermost or midnight twelve. This plate may represent the earth, and the dot at L, London, or any other place at which the clock is designed to show the times of high and low water.

Around this plate is an elliptical shade upon the plate that carries the moon M: the highest points of this shade are marked High Water and the lowest points Low Water: as this plate turns round below the fixed plate N, the high and low water points come successively even with L, and stand just over it at the times when it is high or low water at the given place; which times are pointed out by the sun S, among the twenty-four hours on the dial-plate: and, in the arch of this plate, above twelve at noon, is a plate H, that rises and falls as the tide does at the given place. Thus, when it is high water, (suppose at London,) one of the highest points of the elliptical shade stands just over L, and the tide place H is at its greatest height: and when it is low water at London, one of the lowest points of the elliptical shade stands over L, and the tide place H is quite down, so as to disappear beyond the dial-plate. As the sun S goes round the dial-plate in 24 hours, and the moon M goes round it in 24 hours 50½ minutes, the moon goes so much slower than the sun as only to make 28½ revolutions in the time the sun makes 29½; and therefore the moon's distance from the sun is continually changing; so that at whatever time the sun and moon are together, or in conjunction, in 29½ days afterwards they will be in conjunction again. Consequently the plate that carries the moon moves so much slower than the plate that carries the sun, as always to make the wire a shift over one day of the moon's age on the sun's plate in 24 hours.

In the plate that carries the moon, there is a round hole *m*, through which the phase or appearance of the moon is seen on the sun's plate, for every day of the moon's age from change to change. When the sun and moon are in conjunction, the whole space seen through the hole *m* is black: when the moon is opposite to the sun, (or full,) all that space is white; when she is in either of her quarters, the same space is half black and half white; and different in all other positions, so as the white part may resemble the visible or enlightened part of the moon for every day of her age.

To show these various appearances of the moon, there is a black shaded space, fig. 497, as N *f* F *l*, on the plate that carries the sun. When the sun and moon are in conjunction, the whole space seen through the round hole is black, as at N; when the moon is full, opposite to the sun, all the space seen through the round hole is white, as at F; when the moon is in her first quarter, as at *f*, or in her last quarter, as at *l*, the hole is only half shaded; and more or less accordingly for each position of the moon, with regard to her age; as is abundantly plain by the figure.

The wheel-work and tide-work of this clock are represented by fig. 498, in which A and B are two wheels of equal diameters. A has 57 teeth,

its axis is hollow, it comes through the dial of the clock, and carries the sun-plate with the sun, S, in fig. 496. B has 59 teeth, its axis is a solid spindle, turning within the hollow axis of A, and carrying the moon-plate with the moon, M, in fig. 496. A pinion C, of 19 leaves, takes into the teeth of both the wheels, and turns them round. This pinion is turned round, by the common clock-work, in eight hours, and as 8 is a third part of 24, so 19 is a third part of 57: and therefore the wheel A of 57 teeth, that carries the sun, will go round in 24 hours exactly. But as the same pinion C, (that turns the wheel A of 57 teeth,) turns also the wheel B of 59 teeth, this last wheel will not turn round in less than 24 hours 50½ minutes of time; for as 57 teeth are to 24 hours, so are 59 teeth to 24 hours 50½ minutes, very nearly.

On the back of the moon-wheel of 59 teeth is fixed an elliptical ring D, which, as it turns round, recoils and lets down a lever E F, whose centre of motion is on a pin at F; and this, by means of an upright bar G, raises and lets down the tide-plate H, twice in the time of the moon's revolving from the meridian to the meridian again. The upper edge of this plate is shown at H, in fig. 496, and it moves between four rollers, R R R R, in fig. 498.

Mr. Ferguson states that he made one of these clocks to go by the movement of an old watch in the following manner: to the end of the axis of the first or great wheel of a watch, which goes round in four hours, he put a wheel of 20 teeth to turn a wheel of 40 teeth on the axis of the pinion C; by which means, that pinion turned round in eight hours, the wheel A in 24 hours, and the wheel B in 24 hours 50½ minutes.

The writer of the different branches of Horology in Dr. Rees's *Cyclopædia* states, that there is an inaccuracy in the numbers of the wheel-work adopted in the dial-work of this clock, which would render it too imperfect to be used for a considerable length of time without a new rectification, even provided the motions of the sun and moon, or, more properly speaking, of the earth and moon, were quite equable, as the construction supposes, which inaccuracy, he states, may thus be explained.

"As the pinion of 19 drives both the wheels of 57 and 59, when the former has performed a revolution in a solar day, the latter falls two teeth short of a revolution, which it completes not until two teeth of the second revolution of the wheel 57 have been again impelled, so that in every 24 hours the little moon loses 2-59 of its revolution, which is a part of a relative retrograde motion, as it regards any point for instance, the upper hour xii, in the solar-plate, so that as often as 2 are contained in 59, so many day-spaces must there be on the solar-plate, figured in a retrograde direction, as the figures regard the principal plate; but the value of 2-59 is 29½ exactly, which number of days measures the lunation according to these wheels exactly: there is, therefore, a monthly error of $44^m\ 3^s$ almost, which will amount to nearly an entire day in the short space of about 32 lunations.

"But there is, moreover, a practical objection to the two wheels, 57 and 59, being both driven by the same pinion of 19, which is, that being of the same diameter, the distance between their teeth is not the same in both, one

being 1-57th, and the other 1-59th of a semicircle, supposing their teeth and spaces to be respectively equal to one another, but if both wheels are cut in the cutting-engine by the same cutter, the inequality will fall in the teeth entirely; in either cases, the action of one of the teeth must be bad if the other is properly proportioned, and periodic jerks will be the consequence, which, in wheel-work going by a clock or watch movement, ought to be avoided. Whether or not Mr Ferguson had the dial of the clock at Hampton Court in his eye when he contrived the simple mechanism of this clock, we will not undertake to affirm; but we think it extremely probable that he had, particularly as he has copied the position of the annular train in another of his clocks. Being in the habit of calculating numbers proper for representing given periods of time in clocks, watches, orreries, &c. we have turned our thoughts towards the improvement of this clock, as well as of other pieces of mechanism, so far as relates to accuracy; and beg leave to lay before the reader the alteration that has occurred to us, for rendering the clock before us more perfect than it is in the state above described.

"When describing the Hampton Court clock, we endeavoured to prove that when the moon's age is indicated by the difference of the velocities of the two hands, moving in the same direction, and representing the sun and moon, the latter ought to pass the xii o'clock point, on each day 50^m 473 nearly later than on the preceding day; but by Mr Ferguson's calculations we see the daily retrogradation is 50^m 526, and the difference .053 amounts to an entire day's motion in a little more than 952 days; or somewhat upwards of 32 lunations, as we have stated. What therefore we want, in this case, is a couple of divisible numbers that shall be to each other very nearly in the ratio of 24^h to 24^h 50^m 473, which numbers, by a peculiar arithmetical process, become familiar to us by practice, we have determined to be 2368 : 2451. These are the nearest possible numbers that can be got without ascending higher in the scale of continual ratios, and are luckily capable of reduction into composite numbers thus: 2368 taken as a product is equal to 74×32 and $2451 = 57 \times 43$; therefore the train 43-74ths $\times$ 57-32ds will be the wheel-work required; the solar wheel of 74 teeth being made to revolve with a tube as an arbor in 24 hours, by the clock movement, must impel the wheel of 43 placed on a stud, or otherwise on the front plate of the frame, at one side of it, and this wheel of 43 must have the next driver, 32, pinned to it, to impel the last wheel, 57, or lunar wheel, placed on a solid arbor, concentrically behind the solar wheel, according to Mr Ferguson's position, and the dials and other designs of the clock face may remain precisely as described; so that instead of the pinion of 19 impelling two unequal wheels at once, we shall have a pair of small wheels pinned together, one impelled by, and the other impelling its fellow, where the motion must be taken from an arbor of twelve hours, carrying a wheel of 37 to actuate the 74 in twenty-four hours, instead of from one of eight hours, as Mr Ferguson proposed; which mode is equally practicable.

"As a proof of the accuracy of our calculation, we have by direct proportion as 2368 : 2451 : : 24^h : 24^h 50^m 4729729, &c.: hence the deviation from the data is here only 0000271 of a minute in each lunar day, which will not amount to an error of an entire day in less than 1,862,472 such days, and therefore, may be assumed as no bad substitute of the truth itself; seeing the clock will never be expected to go so long without clearing or stoppage from some external cause.

"Should it occur to the reader that 32 lunations constitute a period long enough for the clock of Mr Ferguson to go, before a new rectification, we beg leave to suggest to him, that in the space of a lunar day, there are two tides and two ebbs, consequently an error of three-quarters of an hour in each

lunation will place the tide-plate H, three hours wrong in the space of about four months, and in nearly eight months an high water will be changed into low water, and the reverse in the next eight months, which is certainly an indispensable error.

"That the clock-maker may not be at a loss how to apply the remedy we have proposed for the inaccuracy of Mr Ferguson's solar and lunar wheels, we shall conclude our description of the clock before us with an account of the exact dimensions of the parts proposed to be substituted. If we take the wheel of communication of 37 teeth at 12 per inch, measured at the pitch line, its geometrical diameter will be 98 or 98-100ths of an inch, and its practical diameter, with the addendum for the ends of the teeth, 1.04; the wheel of 74 being double will have its geometrical diameter equal to 1.96, and its practical one 2.02; the fellow of this last or solar-wheel has its geometrical diameter by the same proportion, 1.14, and its practical one 1.20; the distance of the stud from the centre of motion of the solar and lunar wheels, must necessarily be the sum of the geometrical radii of these two last wheels, namely, $\overline{1.96 + 1,14 \div 2)}$ which is = 1.55; again the sum of the geometrical radii of the remaining two wheels, 32 and 57, must be also equal to 1.55, in order that the centres of motion of the solar and lunar wheels may exactly coincide; but a wheel of a geometrical diameter equal to $\overline{1.55 \times 2)}$ or 3.10 inches and of $\overline{32 + 57)}$ or 89 teeth, will have only about nine teeth per inch, and the practical diameters of wheels 32 and 57, by the same, will be respectively 1.21 and 2.1. The calliper suitable for these proportions and dimensions is given, of their full size and dimensions, in fig. 498*, which needs no farther explanation, except that the wheels 43 and 32 are so nearly of a size that one circle represents both, as pinned together, and revolving with a contemporary motion round a stud or screw in their centre, going into the front plate of the clock-frame. The small wheel of 32 acts deeper into the teeth of its fellow than the 43, by reason of having larger teeth than the other, though the wheel is of the same size."

In the year 1803, the Society for the Encouragement of Arts, &c. presented to Mr John Prior, of Nessfield, Yorkshire, a reward of thirty guineas on account of his contrivance for the striking part of an eight-day clock. As this invention is likely to be useful, we shall describe it here. It consists of a wheel and fly, with six turns of a spiral line, cut upon the wheel for the purpose of counting the hours. The pins below this spiral elevate the hammer, and those above are for the use of the detent. This single wheel serves the purpose of count-wheel, pin-wheel, detent-wheel, and the fly-wheel, and has six revolutions in striking the twelve hours. If we suppose a train of wheels and pinions used in other striking parts to be made without error, and that the wheels and pinions would turn each other without shake or play, then, allowing the above supposition to be true, (though every mechanic knows it is not,) Mr Prior's striking part would be found six times superior to others, in striking the hours 1, 2, 5, 7, 10, 11; twelve times superior in striking 4, 6, 8; and eighteen times in striking 3, 9, and 12. In striking 2, the inventor purposely made an

imperfection equal to the space of three teeth of the wheel; and in striking 3, an imperfection of nine or ten teeth; and yet both these hours are struck perfectly correct. The flies in clocks turn round at a mean, about sixty times for every knock of the hammer, but this turns round only three times for the same purpose: and suppose the pivots were of equal diameters, the influence of oil on them would be as the number of revolutions in each. It would be better for clocks if they gave no warning at all, but the snail piece to raise a weight somewhat similar to the model Mr P. sent for the inspection of that respectable society.

The striking part of this clock is represented in fig. 499.

A, the larger wheel, on the face of which are sunk or cut the six turns of a spiral.

B, the single worm screw, which acts on the above wheel, and moves the fly C.

D, the spiral work of the wheel A. The black spots show the grooves into which the detents drop on striking the hour.

E, the groove into which the locking piece F drops when it strikes 1, and from which place it proceeds to the outward parts of the spiral in the progressive hours, being thrown out by a lifting piece H at each hour; the upper detent G being pumped off with the locking piece F, from the pins on the wheel A.

In striking the hour of 12, the locking piece, having arrived at the outer spiral at H, rises up an inclined plane, and drops by its own weight into the inner circle, in which the hour 1 is to be struck, and proceeds on in a progressive motion through the different hours till it comes again to 12.

I, the hammer-work made in the common way, which is worked by thirteen pins on the face of the spiral.

Fig. 500, K, the thirteen pins on the face of the spiral, which work the hammer-work.

L, the outer pins which lock the detent.

M, the pump spring to the detent.

In the fourth century, an artist named James Dondi constructed a clock for the city or Padua, which was long considered as the wonder of the period. Besides indicating the hours, it represented the motions of the sun, moon, and planets, as well as pointed out the different festivals of the year. On this account Dondi obtained the surname of Horologio, which became that of his posterity. A short time after, William Zelander constructed for the same city a clock still more complex; which was repaired in the sixteenth century by Janellin Turrianus, the mechanist of Charles V.

But the clocks of the cathedrals of Strasburgh and of Lyons are much more celebrated. That of Strasburgh was the work of Conrad Dayspodius, a mathematician of that city, who finished it about 1573. The face of the basement of this clock exhibits three dial plates; one of which is round, and consists of several concentric circles; the two interior ones of

which perform their revolutions in a year, and serve to mark the days of the year, the festivals, and other circumstances of the calendar. The two lateral dial-plates are square, and serve to indicate the eclipses both of the sun and moon.

Above the middle dial-plate, and in the attic space of the basement, the days of the week are represented by different divinities, supposed to preside over the planets from which their common appellations are derived. The divinity of the current day appears in a car rolling over the clouds, and at midnight retires to give place to the succeeding one. Before the basement is seen a globe borne on the wings of a pelican, around which the sun and moon revolved; and which in that manner represented the motion of these planets, but this part of the machine, as well as several others, has been deranged for a long time. The ornamental turret, above this basement, exhibits chiefly a large dial in the form of an astrolabe, which shows the annual motion of the sun and moon through the ecliptic, the hours of the day, &c. The phases of the moon are seen also marked out on a particular dial-plate above. This work is remarkable also for a considerable assemblage of bells and figures, which perform different motions. Above the dial-plate last mentioned for example, the four ages of man are represented by symbolical figures: one passes every quarter of an hour, and marks the quarter by striking on small bells; these figures are followed by Death, who is expelled by Jesus Christ risen from the grave: who, however, permits it to sound the hour, in order to warn man that time is on the wing. Two small angels perform movements also; one striking a bell with a sceptre, whilst the other turns an hour-glass at the expiration of an hour. In the last place, this work is decorated with various animals, which emitted sounds similar to their natural voices; but none of them remain, except the cock, which crows immediately before the hour strikes, first stretching out its neck and clapping its wings. Indeed it is to be regretted that a great part of this curious machine is now entirely deranged.

The clock of the cathedral of Lyons is of less size than that of Strasburgh, but is not inferior to it in the variety of its movements; it has the advantage also of being in a good condition. It is the work of Lippius be Basle, and was exceedingly well repaired in the last century by an ingenious clockmaker of Lyons, named Nourisson. Like that of Strasburgh, it exhibits, on different dial-plates, the annual and diurnal progress of the sun and moon, the days of the year, their length, and the whole calendar, civil as well as ecclesiastic.

The days of the week are indicated by symbols more analogous to the place where the clock is erected; the hours are announced by the crowing of a cock, three times repeated, after it has clapped its wings, and made various other movements. When the cock has done crowing, angels appear, who by striking various bells, perform the air of a hymn; the annunciation of the virgin is represented also by moving figures, and by the descent of a dove from the clouds; and after this mechanical exhibition the hour strikes. On one of the sides of the clock is seen an oval dial-plate, where the hours and minutes are indicated by means of an index, which lengthens or contracts itself, according to the length of the semi-diameter of the ellipsis over which it moves.

A very curious clock, the work of Martinot, a celebrated clock-maker of the seventeenth century, was formerly to be seen in the royal apartments at Versailles. Before it struck the hour, two cocks on the corner of a small edifice crowed alternately, clapping their wings; soon after, two lateral doors of the edifice opened, at which appeared two figures bearing cymbals, beat upon by a kind of guards with clubs. When these figures had retired, the centre door was thrown open, and a pedestal, supporting an equestrian statue of Louis XIV. issued from it, while a group of clouds separating, gave a passage to a figure of Fame, which came and hovered over the statue. An air was then performed by bells; after which the two figures re-entered, the two guards raised up their clubs, which they had lowered as if out of respect to the presence of the king, and the hour was then struck.

While, however, we have thought it right to describe these ingenious performances of foreign artists, we must not neglect to mention the equally ingenious workmanship of some of our own countrymen. We now refer to two clocks made by English artists as a present from the East India Company to the Emperor of China. These two clocks are in the form of chariots, in each of which a lady is placed in a fine attitude, leaning her right hand upon a part of the chariot, under which appears a clock of curious workmanship, little larger than a shilling, which strikes and repeats, and goes for eight days. Upon the lady's finger sits a bird, finely modelled and set with diamonds and rubies, with its wings expanded in a flying posture, and which actually flutters for a considerable time by touching a diamond button below it; the body of the bird, in which are contained the wheels that animate it as it were, is less than the 16th part of an inch. The lady holds in her

left hand a golden tube, little thicker than a large pin, on the top of which is a small round box, to which is fixed a circular ornament not larger than a sixpence, set with diamonds, which goes round in or near three hours in constant regular motion. Over the lady's head is a double umbrella, supported by a small fluted pillar the size of a quill, and under the larger of which a bell is fixed, at a considerable distance from the clock, with which it seems to have no connection, but from which a communication is secretly conveyed to a hammer that regularly strikes the hour, and repeats the same at pleasure, by touching a diamond button fixed to the clock below. At the feet of the lady is a golden dog.

In a work like the present, however we may wish to pursue this interesting subject through its progressive steps of improvement, and to do justice to the numerous scientific and ingenious men who have from time to time effected those improvements, we are compelled to confine ourselves within certain limits, which preclude us from entering more fully into detail in this article; we therefore refer such of our readers, who wish to pursue the subject, to the catalogue of writings in Dr Young's Natural Philosophy.

We shall next proceed to give a description of the mechanism of an ordinary watch, and to annex thereto a useful set of tables, published originally by Mr W. Stirt.

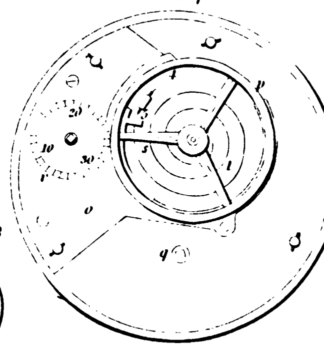
WATCHES.

Figure 501 represents the interior works of an ordinary watch with the crown-wheel escapement, as they remain on the pillar-plate when the upper part of the frame, shown by fig. 505, is unpinned and removed; and fig. 502, which is a section of the whole frame and its contents, shows the connection of all the parts, as though the calliper were in one right line. These two figures, by having the same letters of reference, mutually explain each other. The mainspring which actuates all the wheels and pinions, that are called, in one general term, the movement, is contained in the circular box, *a*, seen in the different views in the separate figs. 501, 502, and 508, in the last of which its parts are given in a detached state, viz. the box; the relaxed spring immediately above lying in a spiral form; the arbor with its pin, on which the interior end of the spring is hooked, and the lid through which the pivot of the arbor penetrates; this spring is forced into the box by a tool on purpose when it is strong; and then the exterior end is hooked to a pin in the circular edge of the box; so that if the box is made to turn round while the arbor is held fast, the spring begins to coil at the centre, and is thereby said to be wound up. The same effect would be produced if the box were held fast, and the arbor only were turned; but in the latter case the chain, which requires to be uncoiled from the spring-box as this spring is wound up, would remain unmoved; it is necessary therefore that the box be turned while the arbor is at rest, which is thus effected: one end of the chain

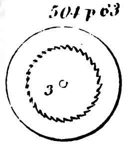
From 501 to 509

501 p 62

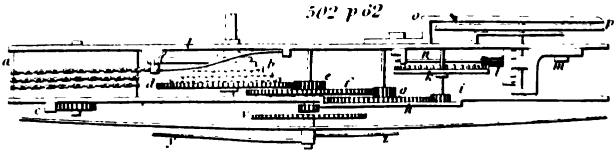
505 p 62.5



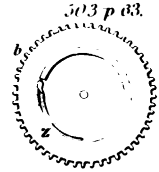
504 p 63



502 p 62



503 p 63.



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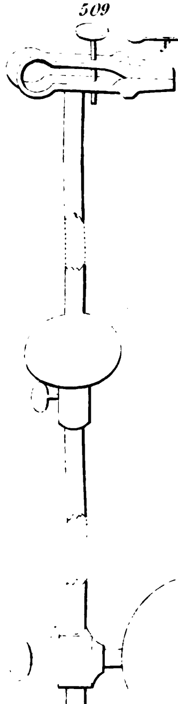
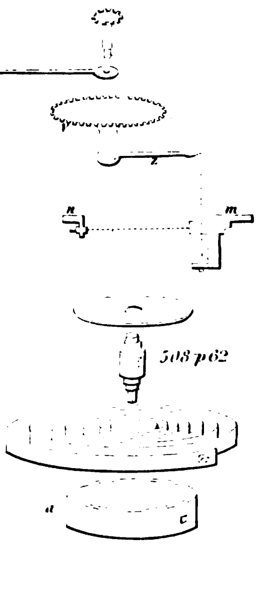
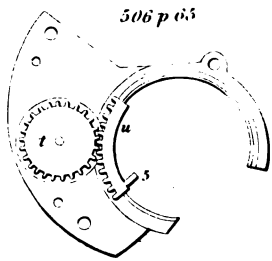


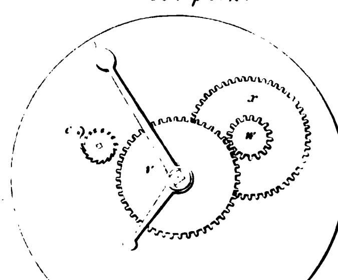


508 p 62

506 p 63



507 p 63.6.



is made fast to the side of the spring-box, and the other to the fusee *b*, after being coiled several times round the circumference of the box; then as the square end of the spring-box arbor is held by the small ratchet and click *c*, seen on the reversed face of the pillar-plate in fig. 507, so that it cannot revole, it is obvious that inserting a key on the square of the fusee arbor, and turning it in a proper direction, will wind the chain upon the spiral groove of the fusee, while it is unwound from the box; and during this operation the spring will be coiled up to the centre of the box, or put into its state of greatest tension for pulling the fusee back again. The rapid motion which the fusee would have in a retrograde direction when pulled by the whole force of the coiled spring, is prevented by the train of wheel-work and balance, thus: the great wheel *d*, is not fast to the thick end of the fusee, as appears in the drawings, but carries a click and click-spring *z*, as seen in fig. 503, while the ratchet-wheel, seen in fig. 504, is made fast to the fusee; the consequence of which contrivance is, that while a key applied to the fusee arbor winds up the watch and fills the fusee groove with the chain, until the guard driven by it catches the beak at the small end of the fusee, the click, in fig. 503, slides over the teeth of the ratchet in fig. 504, without acting on them, and thus leaves the great wheel *d* at rest, in connection with the pinion *e* on the centre or minute wheel arbor; but when the spring acts on the fusee in a contrary direction, the click attached to the great wheel is laid hold of by the teeth of the ratchet, which thus makes it fast to the end of the fusee; or in order words, until the spring wants winding up again, which usually happens once is 28 or 30 hours; but it is commonly wound up once in 24 hours more or less. The action of the great wheel *d*, on the pinion *e*, is that of a long lever driving a short one; or this wheel may be said to act under a mechanical disadvantage, when an increase of velocity, but a loss of power, is experienced by the pinion; again, on the same central arbor of this pinion *e* is rivetted the centre wheel *f*, which revolves in an exact hour, as we shall see presently, and this wheel drives the pinion *g*, on the arbor of the third wheel *h*, also with a mechanical disadvantage, for the force it imparts to the pinion *i*, on the arbor of the contrate wheel, is again diminished in the ratio of the diameter of the wheel to that of its pinion; thus the force of the mainspring is continually diminishing as it is transmitted through the train, and when the contrate wheel comes to be actuated, it has just force enough to drive the horizontal pinion on the balance-wheel *l*, so that the alternate impulse given by its teeth to the pallets of the balance verge are just sufficient to prepetuate the oscillation from right to left, under all the obstacles of friction, dirt, wear, and the air's resistance. It is a curious fact that the crown-wheel escapement, though the oldest that we know of, is still the most in use in common watches, probably from the facility with which it is constructed; for certainly it is more under the influence of the irregularities of the mainspring's force than any other escapememt. The properties and action of this escapement have been minutely explained in page 78, vol. ii, of the article Escapement, with reference to fig. 523, to which explanation and figure we request our reader's attention.

In order that the force applied to pallets of the verge at each oscillation may not sensibly vary, it was found necessary to equalize, as much as possible, the variable forces of the mainspring in its different states of tension; and the most practical way of doing this has been found, to convert the cylinder on the arbor of the great wheel, which would have

been proper for a gravitating body, used as a maintaining power, into a figure of a parabolic form, that is, into a solid, generated by the revolution of a parabola, in order that, as the force of the spring becomes greater by increased tension, its action on the great wheel might be lessened in a similar proportion, by a gradual decrease of the radius of the fusee, round which the chain is wound, to impart the force thus modified. Every separate spring, therefore, has not only its average force proportioned to the balance it is destined to actuate, when diminished by transmission through a given train, but requires its scale of varying forces to be nicely counteracted in every degree of tension by the shape of the fusee; and this is done by means of a tool, called a fusee adjusting tool, which is nothing more than a lever with a sliding weight attached to the square end of the fusee arbor, as represented in fig. 509; for when the weight on the lever is an exact counterpoise to the force of the mainspring in every part of the successive revolutions of the fusee, as the spring is wound up by the lever instead of a key, then the shape of the fusee is proper, but not otherwise. Hence, whenever a new mainspring is put to a watch, the fusee ought to be adjusted in the fusee engine according as the adjusting tool determines.

The comparative forces of the spring at the extreme ends of the fusee may be adjusted by the small ratchet *c*, on the back of the pillar-plate in fig. 507, but when the spring is put to a suitable degree of tension to act well at both extremities of the fusee, it must not be altered by the ratches' click, but the intermediate forces must be equalized by a due shape given to the fusee. We have insisted the more on this part of the mechanism being attended to, because, as the *primum mobile*, it is the basis of all other motions. The number of rounds that the spiral of the parabolic fusee may be cut into depends on the length of the pillars of the frame, or, which is the same thing, the shallowness of the watch. The French frequently leave out the fusee, and attempt to equalize the forces of the mainspring by tapering it; and with detached escapements, this mode may sometimes answer tolerably, but with the crown-wheel escapement a fusee is indispensable. Again, the number of teeth in the great wheel, and in the centre pinion, depends on the number of rounds in the spiral of the fusee.

In a thirty-hours' watch, with six turns of the fusee, the great wheel must have $\frac{30}{6}$ or five times as many teeth as the centre pinions; so that if this has six leaves, the wheel must have $5 \times 6 = 30$ teeth; but if eight, then $5 \times 8 = 40$; if the spiral has seven turns, the great wheel 48, and the pinon 12, then the

time of going will be $\frac{48}{12} \times 7 = 28$ hours; also, if there be $5\frac{1}{2}$ turns on the fusee, 50 teeth in the wheel, and 10 leaves in the pinion, the period of going will be $27\frac{1}{2}$ hours, or $\frac{50}{40} \times 5\frac{1}{2} = 5 \times 5\frac{1}{2} = 27\frac{1}{2}$; but if 24 hours only were required as the period, with six turns and a pinion of 12, the great wheel would be required to have 48.

Thus when an alteration is made in either the pinion, the wheel, or the turns in the fusee, a corresponding variation may be made in the others, to produce the same period of going, but still the centre wheel revolves once in an hour. In the commonest watches the pinions have only six leaves each, which do not act so well as pinions of higher numbers; but in the best watches, and in all chronometers, the leaves and teeth are more numerous. The pivot-holes, particularly of the verge and escapement arbor, have jewels for the purpose of diminishing the friction, in the best watches; but detached and remontoire escapements are the best correctives of the unequal impulses given through the medium of the train in the different states of its foulness.

The potence *m*, and small or counter potence *n*, that hold the pivots of the balance-wheel, are small cocks seen in fig. 502, both in their attached and detached states, and are screwed to the top or upper plate within the frame; but the springs, buttons, and joints of the case, are not exhibited, as forming no part of the movement. Fig. 505 represents the outer face of the upper plate, with the balance *p*, the cock *o*, and balance-spring *s*, called the pendulum-spring, from its having the properties of the pendulum; by means of this spring, not only is the regulation made steady, but the adjustment for time is effected. In every balance-spring there is a certain length, to be taken as the effective length, by which the going of the watch to which it is applied is limited to exact performance; and when this length is determined by experiment, a pin is put in the stud that holds the exterior ends, as at 4, in fig. 505, to prevent its being altered; but as the variation of temperature will alter the momentum of the moving-balance, the effect thereby produced is a loss of time in the rate, in hot weather, and a gain in cold weather, by an alternate increase and decrease in the dimensions of the balance itself, as well as by some alteration in the spring. To remedy this defect, in an ordinary watch, the contrivance shown in fig. 506 is introduced; the wheel *t* is placed under the graduated circle *r*, seen in fig. 505, and a circular rack *u*, fig. 506, that holds the curb or slit-piece 5, seen in both figures, is moved by a sliding motion given to it, when a key is applied to the squared arbor of the figure circle, and thus the effective length of the spiral spring is limited by the position of the curb 5; and according as the key is turned forwards or backwards, towards the words 'fast' or 'slow' engraved on the cock, the shortened or lengthened spring alters the rate of going, till the proper length is found that suits the season in question.

In Harrison's time-piece the curb was moved by an expansion-lever of two metals, that acted by means of the change of temperature; but in the best chronometers of more recent dates, the compensating levers constitute the three portions into which the rim of the balance is divided, and the adjust-

ment for time, as well as compensation for temperature, are by means of heavy screws, which form a part of the moving balance. In these more perfect machines, the length of the spring, which is now made helical or cylindrical, is first determined such, that the long and short vibrations are performed in the same time, and this is called the isochronal lengths, which is not afterwards altered by subsequent adjustments.

The last portion of the watch which demands our explanation is the dial-work, for producing the hours and minutes; this will be easily understood by reference to figs. 502 and 507. Then the pinion called the cannon-pinion, seen near the minute-hand in fig. 502, is inserted on the arbor of the hour or centre wheel, to which it fits rather tight by friction, it revolves therewith in an hour, and receives the minute or hour-hand on its protruding squared end; then this pinion drives the wheel x round a stud on the pillar-plate and with it a pinion w made fast to its centre; which pinion again drives a second wheel, v, round the tube of the cannon-pinion in twelve hours; and to this the hour-hand is attached. This diminution of twelve revolutions from the cannon-pinion to the hour-wheel might be effected by one pinion driving a single wheel of twelve times its number of teeth; but as the motion must be brought back to the centre of the dial again, two more wheels, or a wheel and pinion, are necessary to be introduced, and these are therefore made a part of the train, and no large wheel or small pinion is wanted, for the ratio 12; 1 may be more conveniently obtained by two factors, *viz.* 4 : 1 and 3 : 1; thus, suppose the cannon-pinion to have 15 leaves, its wheel may have $4 \times 15 = 60$ teeth for wheel x, and if the wheel v be the same, its pinion will be $\frac{60}{3} = 20$, and the train $\frac{60}{15} \times \frac{69}{20} = \frac{360}{30} = \frac{72}{6}$ or $\frac{60}{5} = \frac{12}{1}$ or 12; so that when the pinions are fixed upon for the dial work, the wheels are readily determined, and *vice versa.*

The following Tables, somewhat differently arranged, were published by W. Stirt, an ingenious balance-wheel and fusee cutter.

A TABLE OF TRAINS FOR WATCHES.

Showing the Number of Turns on the Fusee and Teeth in the Balance-wheel, with the Beats in an Hour, and the number of Seconds in which the Contrate or Fourth Wheel revolves; for the easy Timing of Watches by the Vibrations of the Pendulum.

9 *Teeth in the Balance-wheel.*

Second wheel 58 6 Third wheel pin.	60 8	60 6	60 6	60 6	60 6	64 6	64 8
Third wheel 56 6 Contrate pin.	56 7	58 6	58 6	60 6	60 6	60 6	60 8
Contrate wheel 54 6 Balance pin.	80 6	52 6	56 6	54 6	60 6	54 6	80 6
Beats 14,616 in an hour	14,400	15,080	16,240	16,200	18,000	17,280	14,400
Seconds $39\frac{9}{10}$ in which the 4th wheel revolves.	60	$37\frac{1}{4}$	$37\frac{1}{4}$	36	36	$33\frac{3}{4}$	60

A TABLE OF TRAINS FOR WATCHES *continued.*

11 *Teeth in the Balance-wheel.*

Second wheel 48 6 Third wheel pinion .						54 6	54 6	56 7	56 6	56 6
Third wheel 45 6 Contrate pinion . .						45 6	50 6	45 6	54 6	56 6
Contrate wheel 70 6 Balance pinion . .						65 6	60 6	78 6	54 6	55 6
Beats 15,400 in an hour						16,087	16,500	17,160	16,632	17,567
Seconds 60, in which the 4th wheel revolves						$53\frac{1}{3}$	48	60	$42\frac{2}{3}$	$41\frac{1}{4}$
58 6	58 6	58 6	58 6	58 7	60 6	60 6	60 6	60 6	60 6	60 6
52 6	54 6	54 6	56 6	56 6	50 6	52 6	54 6	54 6	54 6	55 6
52 6	52 6	54 6	54 6	56 6	52 6	52 6	50 6	52 6	54 6	52 6
15,973	16,588	17,226	17,817	15,879	15,888	16,520	16,500	17,160	17,820	17,477
$42\frac{3}{4}$	$41\frac{1}{3}$	$41\frac{1}{3}$	$39\frac{3}{4}$	$54\frac{1}{3}$	43	$41\frac{1}{2}$	40	40	40	39
60 6	60 7	60 8	60 8	60 6	60 8	60 7	62 6	62 7	63 6	63 6
56 6	56 6	56 7	56 7	60 6	60 6	60 7	54 6	58 6	54 6	56 7
50 6	56 6	74 6	78 6	48 6	56 6	60 6	52 6	52 6	50 6	56 6
17,111	16,426	16,280	17,160	17,553	15,400	16,163	17,935	16,324	17,325	17,248
$38\frac{1}{2}$	40	60	60	36	48	49	$38\frac{1}{4}$	45	38	$42\frac{3}{4}$
64 6	64 6	65 7	70 8	70 7	72 8	72 7	80 8	75 10	72 9	72 9
50 6	52 6	62 7	54 7	63 7	63 7	64 7	72 8	72 9	66 8	60 8
50 6	52 6	59 7	68 6	58 7	54 6	58 7	68 8	66 8	60 6	54 6
16,296	17,625	15,250	16,830	16,408	16,035	17,142	16,830	13,200	13,200	11,880
$40\frac{1}{2}$	39	$43\frac{3}{4}$	$53\frac{1}{3}$	40	$44\frac{1}{2}$	$38\frac{1}{4}$	40	60	66	60

13 *Teeth in the Balance-wheel.*

Second wheel 48 6 Third wheel pinion .						48 6	52 6	54 6	54 6	54 6
Third wheel 45 6 Contrate pinion . .						45 6	52 6	50 6	52 6	52 6
Contrate wheel 66 6 Balance pinion . .						68 6	52 6	50 6	48 6	50 6
Beats 17,160 in an hour						17,680	16,925	16,274	16,224	16,900
Seconds 60, in which the 4th wheel revolves						60	$46\frac{1}{2}$	48	46	46
54 6	54 6	55 6	56 7	56 6	56 6	56 6	56 6	56 6	58 6	58 6
52 6	52 6	51 6	45 6	50 6	50 6	52 6	52 6	54 6	48 6	50 6
51 6	52 6	51 6	66 6	50 6	51 6	48 6	50 6	49 6	52 6	50 6
17,238	17,576	17,219	17,160	16,851	17,188	16,824	17,525	17,836	17,425	17,453
46	46	$46\frac{1}{4}$	60	$46\frac{1}{2}$	$46\frac{1}{2}$	$44\frac{1}{2}$	$44\frac{1}{2}$	$42\frac{3}{4}$	$46\frac{3}{4}$	$44\frac{2}{3}$
60 6	60 8	60 6	60 6	60 7	60 6	60 7	60 8	60 7	60 8	60 6
48 6	48 6	50 6	50 6	54 6	54 8	56 7	56 7	58 7	58 6	60 7
48 6	66 6	46 6	48 6	52 6	60 6	56 6	66 6	56 6	56 6	48 6
16,640	17,160	16,611	17,333	17,382	17,550	16,640	17,160	17,234	17,593	17,828
45	60	43	43	$46\frac{2}{3}$	54	$52\frac{1}{2}$	60	$50\frac{2}{3}$	$49\frac{1}{2}$	42
60 8	60 6	62 7	63 7	63 7	64 7	64 7	64 8	64 8	65 7	70 8
60 6	60 7	56 7	52 6	60 7	52 6	60 7	60 8	64 8	62 7	60 7
54 6	56 7	56 6	51 6	60 7	50 6	60 7	66 6	72 7	58 7	52 6
17,550	17,828	17,194	17,238	17,191	17,168	17,464	17,160	17,115	17,717	16,900
48	42	$50\frac{1}{4}$	$46\frac{1}{4}$	$46\frac{2}{3}$	46	$45\frac{3}{4}$	60	$56\frac{1}{4}$	$43\frac{1}{2}$	48
70 8	72 8	72 8	74 8	74 8	75 10	75 10	80 10	96 12	96 12	90 10
66 8	52 6	70 8	64 8	68 8	72 9	72 9	60 8	75 10	75 10	90 10
64 7	52 6	68 8	63 7	68 8	70 7	72 9	60 8	80 8	88 8	90 10
17,160	16,673	17,403	17,316	17,400	15,600	12,480	15,600	15,600	17,166	18,954
50	$44\frac{3}{4}$	$52\frac{1}{2}$	$48\frac{2}{3}$	60	60	60	60	60	60	$44\frac{1}{2}$

A Table of Trains for Watches *continued.*

15 Teeth in the Balance-wheel.

Second wheel 48 6 Third wheel pinion . Third wheel 45 6 Contrate pinion . . Contrate wheel 54 6 Balance pinion . . Beats 16,200 in an hour . . . . . . Seconds 60, in which the 4th wheel revolves						48 6 45 6 58 6 17,400 60	48 6 45 6 60 6 18,000 60	54 6 48 6 46 6 16,560 50	54 6 48 6 48 6 17,280 50	54 6 48 6 64 8 17,280 50
54 6 50 6 48 6 18,000 48	56 7 45 6 56 6 16,800 60	56 7 45 6 58 6 17,400 60	56 7 45 6 60 6 18,000 60	56 6 48 6 46 6 17,173 48	56 7 60 8 60 6 18,600 60	58 6 48 6 46 6 17,786 $46\frac{3}{4}$	58 6 50 8 58 6 17,520 $59\frac{1}{2}$	60 8 48 6 58 6 17,400 60	60 8 48 6 60 6 18,000 60	60 8 56 7 48 6 14,400 60
60 8 56 7 56 7 14,400 60	60 7 56 7 58 7 17,044 $52\frac{1}{2}$	60 8 56 7 58 6 17,400 60	60 8 56 7 60 6 18,000 60	60 8 56 7 60 7 15,386 60	60 6 60 8 48 6 18,000 48	60 6 60 10 48 6 14,400 60	60 6 60 8 56 7 18,000 48	60 6 60 10 58 6 17,400 60	60 10 60 6 60 6 18,000 60	60 6 60 10 64 8 14,400 60
60 8 64 8 66 7 16,971 60	60 8 64 8 70 7 18,000 60	62 8 60 8 60 6 17,437 $61\frac{2}{3}$	63 7 54 7 50 6 17,356 $51\frac{3}{4}$	63 7 56 7 56 7 17,280 50	64 8 45 6 56 6 16,800 60	64 8 60 8 58 6 17,400 60	64 8 60 8 60 6 18,000 60	64 6 60 10 70 8 16,800 $56\frac{1}{4}$	65 7 56 7 56 7 17,828 $48\frac{1}{3}$	70 6 60 10 48 6 16,800 $51\frac{1}{3}$
70 7 60 10 70 7 18,000 60	70 8 64 8 50 6 17,500 $51\frac{1}{3}$	70 8 64 8 58 7 17,400 $51\frac{1}{3}$	70 10 65 8 60 6 17,062 $56\frac{3}{4}$	72 6 60 10 48 6 17,280 50	72 8 64 8 50 6 18,000 50	72 8 64 8 54 7 16,662 50	72 8 64 8 64 8 17,280 50	72 8 65 8 64 8 17,550 49	75 8 64 8 64 8 18,000 48	81 9 72 9 72 9 17,280 50

17 Teeth in the Balance-wheel.

Second wheel 48 6 Third wheel pinion . . . Third wheel 45 6 Contrate pinion . . . . Contrate wheel 50 6 Balance pinion . . . . Beats 17,000 in an hour . . . . Seconds 60, in which the 4th wheel revolves .	56 7 45 6 53 6 18,020 60	60 8 56 7 52 6 17,828 60	64 8 60 8 60 7 17,485 60

G.W.	S.W.P.	T.N.S.	G.W.	S.W.P.	T.N.S.	G.W.	S.W.P.	T.N.S.
48	10	$6\frac{1}{4}$	60	10	5	55	12	$6\frac{6}{44}$
50	10	6	62	10	$4\frac{5}{6}$	56	12	$6\frac{3}{7}$
52	10	$5\frac{3}{4}$	64	10	$4\frac{3}{2}$	58	12	$6\frac{1}{5}$
54	10	$5\frac{5}{9}$	48	12	$7\frac{1}{2}$	60	12	6
55	10	$5\frac{6}{11}$	50	12	$7\frac{1}{5}$	62	12	$5\frac{5}{6}$
56	10	$5\frac{1}{3}$	52	12	$6\frac{12}{43}$	64	12	$5\frac{5}{8}$
58	10	$5\frac{1}{6}$	54	12	$6\frac{2}{3}$			

If we divide double the product of all the four wheels by the product of all the three pinions, the quotient will be the number of beats, as given in any of the trains contained in this table; also, if we take the second and third wheels, and their pinions respectively, as a compound fraction of an hour, they will give the seconds in which the contrate wheel, attached to the latter pinion, will revolve; thus, of $\frac{8}{60}$ of $\frac{7}{56}$ of $60^{m} = 1^{m}$ or 60^{s}, which numbers

are consequently proper for a watch that indicates the seconds; and if the beats be 18,000 or 14,400, there will be five or four beats respectively in a second, which are the best trains for measuring fractional parts of a second.

CHRONOMETERS.

CHRONOMETERS differ from an ordinary watch, principally in the escapement and balance. These machines deserve more than usual attention, as well from their practical utility in navigation, as from the principles on which they are constructed, in which the irregular forces both of impulse and resistance are greatly diminished by the exactness of form and dimension.

In the reign of queen Anne, the British parliament passed an act, offering a reward of 10,000*l*. for any method of determining the longitude within the accuracy of one degree of a great circle; of 15,000*l*. within the limit of forty geographical miles; and of 20,000*l*. within the limit of thirty such miles, or half of a degree; provided such method should extend more than eighty miles from the coast. The hope of obtaining this reward stimulated a watch-maker named Harrison to be indefatigable in his endeavours to effect the required improvement, which eventually led him to apply the principle of the opposite expansions of different metals to a watch to effect a self-regulating curb, for limiting the effective length of the spiral pendulum-spring to correspond to the successive changes of heat and cold, which changes were now known to alter the force of this spring, and the momentum of the balance.

After Harrison had by his industry and perseverance obtained the large reward, the act was repealed, and another substituted, offering separate rewards to any person who should invent a practicable method of determining, within circumscribed limits, the longitude of a ship at sea; for a time-keeper, the reward held forth to the public is 5000*l*. for determining the longitude to or within one degree; 7,500*l*. for determining the same to forty geographical miles; and 10,000*l*. for a determination at or within half a degree. This act, notwithstanding its abridged limits and diminished reward, has produced several candidates; of whom Mudge, the two Arnolds, and Earnshaw, have had their labours crowned with partial success.

Although, in respect to Mudge's time-keeper, great expectations were at first raised, it has, from the complexity of the machinery, and consequent expense attendant upon making it, gradually fallen into disrepute, and is now seldom or ever made. Such of our readers who wish to see its

manner of construction and performance, we must refer to "The Description of Mr Mudge's Time-keeper," published in 1799, by Thomas Mudge, jun.

The chronometer we purpose to lay before our readers is that constructed by Mr Earnshaw, as we are strongly disposed to conclude, from various documents we have seen, and from the similarity so evident in the construction of the escapement, that Mr Arnold derived the knowledge of his principle from Mr Earnshaw.

In Mr Earnshaw's chronometer the escapement is detached, which is the best for the equal measurement of time, because the vibrations of the balance are free from the friction of the wheels, excepting about one-twelfth part of the circle, while the scape-wheel is acting on the pallet to keep up the motion of the balance, which is done with considerably more power and less friction than by any other escapement, as it receives but one blow from the wheel, whilst other escapements receive two; it has also an equal advantage of the same quickness of train, and when the impulse is given to the balance by the wheel, it is given in a similar direction, and not in opposition, as most escapements are which produce a recoil.

The pivots of the balance-axis should be the size of the verge pivots of a good sized pocket-watch, and of the annexed shape, which will greatly add to their strength, the extreme end, or acting part, only being straight; the jewel-hole should be as shallow as possible, so as not to endanger cutting the pivot, and the part of the action of the hole made quite back, with only a very shallow chamber behind to retain the oil; deep holes are very bad, for when the oil becomes glutinous, it will make the pivots stick, so as to prevent the balance from its usual vibration. The pallet should be half the diameter of the wheel, or a little larger, for if smaller, or one-fourth the diameter, as is the case in Arnold's, the wheel, will have too much action on it, which will increase friction most considerably, and likewise cause the balance to swing so much farther to clear the wheel; consequently, a check in the motion of the balance may stop the watch, and cause time-keepers so constructed to stop. The face of the pallet should run in a line of equal distance between the centre of the pallet and its extremity, and not in a right line to its centre, as this causes an increase of friction, and a loss of that power which is obtained by the wheel, acting on the extremity of the pallet. The scape-wheel teeth should form the same direction as the face of the pallet, under-cut for

the purpose of avoiding friction, and maintaining the power, and for safe unlocking. The points of the wheel-teeth must not be rounded off, but left as sharp as possible. The pivots of the scape-wheel are to be very little larger than the balance-pivots.

The wheel is locked by a spring, instead of a detent with pivots, as the French have made them; for those pivots must have oil, and when the oil thickens, the spring of the pivot-detents become so affected by it, as to prevent the detent from falling into the wheel quick enough, which causes irregular time, and ultimately a stoppage of the watch.

When the spring is planted on the side of the wheel, the part on which the wheel rests should be a little short of a right angle, so that the wheel may have a tendency to draw the spring into it; for if sloped the other way, or beyond a right angle, it will have a tendency to push the spring out, in which case the wheel will have liberty to run. The wheel should take no more hold on the spring than just sufficient to stop it, otherwise the friction will be increased. The small return-spring should be as thin as possible at the end fastened to the other spring, but at the outer end a little thicker; the spring should be planted down as close to the wheel as to be just free of it: the discharging pallet about one-third, or near one-half the size of the large or main pallet, the face of it in a right line to the centre, the back of it a little rounding off from the centre. Great care must be used in taking off the edges of this discharging piece to make it round, to prevent cutting the spring, nor can it be made too thin, provided it does not cut; the end of it nearest the balance should be a little more out from the centre of the balance-axis than the lower part of it towards the potence, for counteracting the natural tendency of the spring downwards from the pressure of the scape-wheel; and that part of the spring on which the wheel rests should be sloped a little dow n, togive the wheel a tendency to force it up, to counteract the natural inclination which the wheel has to draw it down by its pressure on it.

The balance is to be made of the best steel, and turned from its own centre to the proper size, and then put into a crucible with as much of the best brass as will, when melted, cover it. The brass will adhere to the steel, and when set, is to be turned to its proper thickness, and hollowed out, so as to leave the steel rim about the thickness of a repeating-spring to a small sized repeating watch. The brass is to be turned to near twice or three times the thickness of the steel; cross

it out with only one arm straight across the centre, and at each end of the arm fix two screws, opposite to each other, through the rim of the balance, to regulate the watch to time. The diameter of the heads of these screws must be about equal to the thickness of the balance, a little more or less is not material. The compensation weights should be made of the best brass, and well hammered, and a groove turned to let the rim of the balance into it: this should be cut into fourteen equal parts, which will leave seven pair of pieces of equal size and weight, one of which pair, being screwed on the rim of the balance at equal distances, will produce an equilibrium. In making balances, great care must be taken that they get no bruises or bendings; for if a bruise be made on one side so as to indent the metal, that part will be less affected by the atmospheric agency of heat and cold than those parts whose pores have not been closed by the same violence.

Balances are likewise spoiled by bending the compensation-pieces, as bending cracks and destroys the compact body of the metal. The soldering up these cracks with a metal very different in expansion to the metal cracked is hurtful, as it is not then possible to bend the compensation-pieces into a true circle, in which case they form so many parts of different circles, that nothing regular can be produced.

To adjust the balance in heat and cold, put the watch into about 85 or 90 degrees of heat by the common thermometer, mark down exactly how much it gains or loses in twelve hours, then put it into as severe a cold as you can get for twelve hours; and if it gain one minute more in twelve hours in cold than in heat, move the compensation-weights farther from the arm of the balance about one-eighth of an inch; and if it gain one minute more in twelve hours in heat than in cold, move the weights one-eighth of an inch nearer to the arm of the balance, and so on in like proportion, trying it again and again, till you find the watch go the same in whatever change of heat or cold you put it in.

Mr Earnshaw has found out a method of obviating the difficulties attendant in making time-keepers go nearly the same in whatever position they might be put. It merely consists in having the balance-spring well and properly made; but if the spring be made as hereafter described, it only requires that the balance should be of equal weight, and it will go, within a few seconds per day, in all positions alike; and if it vibrate not more than 1¼ circle, will, by applying a small weight to that part of the balance which is downwards when in the position that it loses most, correct it with great

accuracy. If it vibrate more than $1\frac{1}{4}$ circle, it will require the weight to be above, instead of below; and after the watch has been going a few months, and its vibrations shorten to $1\frac{1}{4}$ circle, it will go worse and worse by reason of the weight being in the wrong place; therefore, to avoid this evil, it is absolutely necessary to confine the vibrations to $1\frac{1}{4}$ circle, which will produce the most steady performance.

The greatest difficult with which Mr Earnshaw had to contend in the construction of his chronometers was, to find out the invisible properties of that apparent simple part of the machine, calledt he balance-spring. He found, in reasoning on bodies, that watch-springs, when kept constantly in motion, relax and tire like the human frame. In proof of this, let a watch, that has been going a few months, go down; let it remain down for a week or two, and then set it going, when it will, if it be a good time-keeper, and not affected by the weather, go some few second per day faster than it did when it was let down; but it will again lose its quickness in a gradual manner, gaining less and less till it comes to its former rate. Finding, therefore, that isochronal springs would not do, and having made springs of such shape as would render long and short vibrations equal in time, and which constantly lost the longer the watch went, Mr Earnshaw made them of such shape as to gain in short vibrations about five or six seconds per day more than the long ones, which quantity could only be found by long experience; and the way he adopted to prove this, was to try the rate of the watch with the balance vibrating about one-third of a circle, then tried its rate vibrating $1\frac{1}{4}$ circle; and if the short vibrations went slower than the long ones, he found that the watch would lose in its rate; and if equal, it would likewise lose, but that only from relaxation; he found also, if it gain in the short vibrations more than five or six seconds in twenty-four hours, it will in the long run gain on its rate; but if not more than that quantity, and the time-keeper is perfect in heat and cold in every other part, the above properties will render it deserving the name of a perfect time-keeper. Mr Earnshaw found the common relaxation of balance-springs to be about five or six seconds per day on their rates in the course of a year; therefore, if the short vibrations are made by the shape of the spring to go about that quantity faster than the long ones, and as the spring relaxes in going by time, so the watch accumulates in dirt and thickening of the oil, which shortens the vibrations, the

short ones then being quicker, compensated for the evil of relaxation of the balance-spring.

Having thus given our readers Mr Earnshaw's prefatory observations to the Board of Longitude, we shall, in the next place, proceed to give a general description of the different parts of his chronometer.

Fig. 510 represents the time-keeper put together.

Fig. 511, the pillar-plate from which the calliper may be taken; *a*, the height of the pillars.

Fig. 512, the barrel and mainspring; *b*, side view of the barrel.

Fig. 513, the fusee and great wheel, with ratchet to keep it going whilst winding up; *c*, side view of fusee.

Fig. 514, second wheel and pinion; *d*, side view of second wheel.

Fig. 515, third wheel and pinion; *e*, side view of it.

Fig. 516, fourth wheel and pinion; *f*, side view of it.

Fig. 517 represents the upper plate, with the escapement on it, from which the calliper may be taken. In this figure the draftsman has not placed the pallet near enough the wheel; but this is of no consequence, as a proper and exact draft of the escapement on a much larger scale is given in fig. 522; the escapement, therefore, is to be understood from that figure; this only shows the sizes of the wheels.

Fig. 518 represents a side view of the scape-spring which locks the wheel.

Fig. 519, one of the brass weights to be fixed on the rim of the balance for the compensation for heat and cold; *g*, the groove cut in it to receive the rim of the balance. The rim of the balance is cut through in two places in opposite directions, as in fig. 510, and two of these weights are to be placed on the balance-rim, at equal distances, as there represented, and fastened by the screw as at *h*. These weights are to be moved backwards or forwards on the rim of the balance, to make the watch go faster or slower in heat or in cold, as by trial may be found necessary.

Fig. 520 is a side view of said brass weights; *k*, the groove to receive the rim of the balance; its depth shows the breadth for balance-ring.

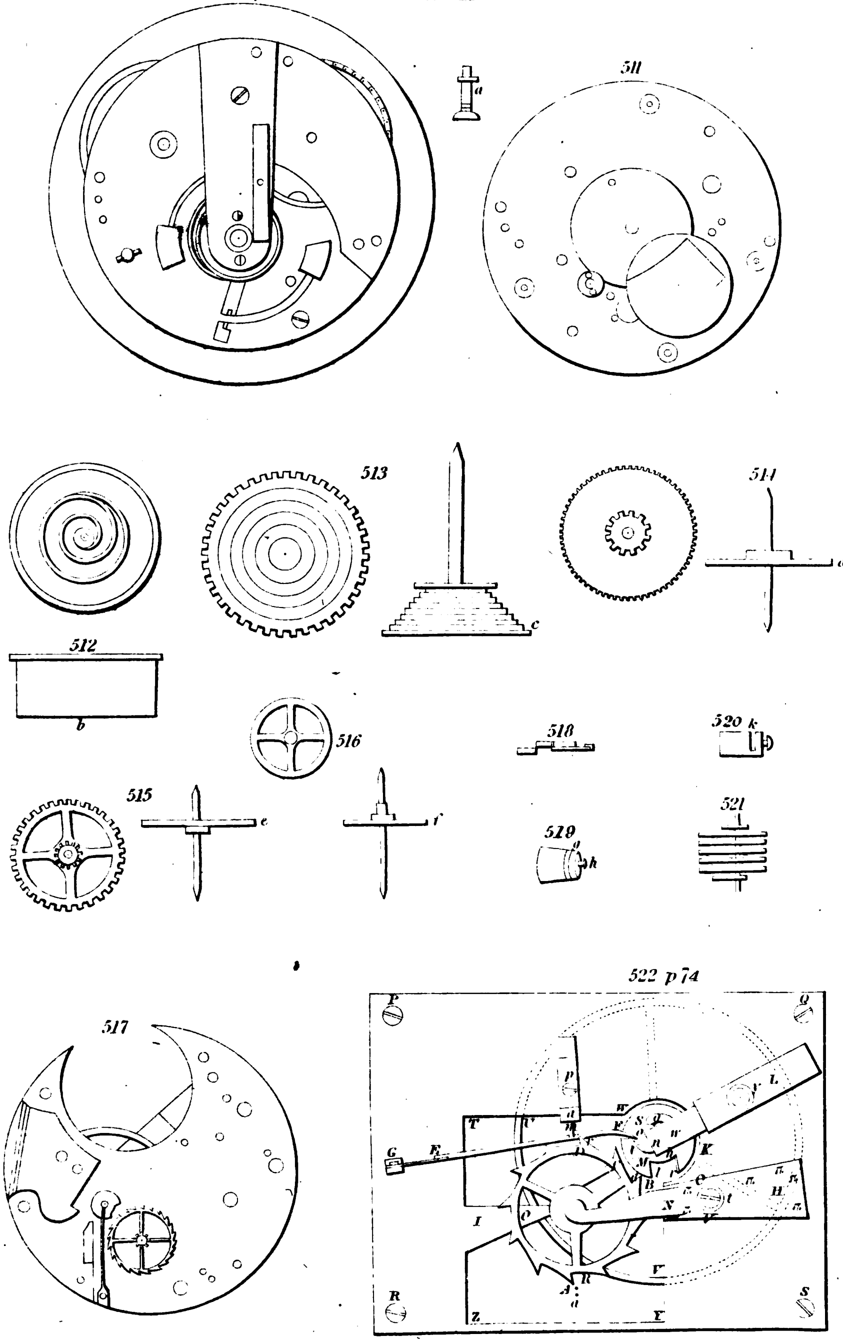
Fig. 521, the cylindrical balance-spring. The only advantage attending the cylindrical shape is, that it is rather easier made, being a saving of about one hour of time; for if the real body or form of the spring be like the shape of the stem of a feather, or common writing quill, it is of no consequence whether it be turned into a spiral or cylindrical figure.

The model, from which the four following figures were taken, contains, besides the parts necessary to explain the nature of the escapement, a box enclosing a spring, which, when wound up, communicates, by means of some more wheels, a force to the balance-wheel sufficient, when the balance is put in motion, to keep it in action for some time. These wheels are contained between two brass plates, fastened together by four upright pillars. The uppermost of these plates is that which is represented in fig. 522, where P Q R S are the four screws that take into the heads of the four pillars abovementioned, and connect it to the remaining part of the model. The plate P Q R S contains, however, the whole of the parts necessary for the present purpose. The side of this plate represented to view, is the undermost when fixed in the model; so that the figure represents this plate as taken off, with the side next to the balance laid upon a table, and the eye is supposed to be placed perpendicularly over it.

In the plate P Q R S is an opening, or a piece taken out, represented by

EARNSHAW'S CHRONOMETER.

510 p 74. From 510 to 522



T U W X Y Z. In this opening the balance-wheel A B C D, pallet M S K, and part of the balance U V, are seen. The balance-wheel is supported by two pieces of brass, O N H, O I; the piece O N H is screwed to the side of the plate nearest to view by a strong screw, V, and made firm by small pins, represented by π π π π π π; these pins are called steady-pins; they are rivetted fast into the supporting-piece O H, and take into holes in the plate P Q R S, made exactly to fit them. The part O N of this supporting piece is supposed to be raised above the part O H by a joint or bend at N: the other supporting-piece O I is fastened to the opposite side of the plate; and between these two pieces the balance-wheel turns freely and steadily in the direction of the letters A B C D. The small wheel M S K is called the large pallet; it is a cylindrical piece of steel, having a notch or piece cut out of it at *l h i*; against the side of this notch is a square, flat piece of ruby, or any hard stone, *h l*, ground and polished very smooth, and fixed into the pallet. The cylinder is so placed, with respect to the balance-wheel, that it may not be more than just clear of two adjoining teeth. E F is a long, thin spring, which is made fast at one end, by being pinned into a stud G, and made to bear gently against the head of an adjusting screw, *m*; the other end is bent a little in the form of a hook; to this spring there is fixed another very slender spring at *y*, which projects to a small distance beyond it. This small spring lies on the side of the thick spring nearest to the balance-wheel. The adjusting screw *m* takes into a small brass cock at *a p*, which is screwed fast to the upper plate by a strong screw. Upon the spring E F there is fixed a semi-cylindrical pin, which stands up perpendicularly upon it, and of a sufficient length to fall between the teeth of the balance-wheel A B C D. This pin is called the locking-pallet, and is placed on the opposite side of the spring represented to view. Through the centre of the cylindrical pallet M S K, a strong steel axis passes, called the verge; the pallet is made fast to this axis, which also passes through the centre of the balance, and is made fast to it; it has two fine pivots at its extremities, upon which it turns very freely, between two firm supporting pieces of brass, screwed firmly, and made as permanent as possible, by steady-pins, to the principal plate. A little above the cylindrical pallet M S K, is fixed a small cylindrical piece of steel, *i n*, having a small part projecting out at *i*, through which the verge also passes; this is called the lifting-pallet, and is from one-third to half the diameter of the large pallet; it fixes upon the verge like a collar, and is made fast by a twist, so as to be set in any position with respect to the large pallet M S K. The end E G of the long spring E F being made very slender, if a small force be applied at the point *o* to press that end out from the wheel A B C D, it yields easily in that direction, turning, as it were, upon a centre at G; it is also made to slide in a groove made in this stud, in such a manner that the end *o* may be placed at any required distance from the centre of the verge.

Having described the several parts as they appear in the figure, we next come to their situation or connection with respect to each other. Let the long spring E F be supposed to be so placed that the end of the slender spring *y i* may project a little way over the point of the lifting-pallet *i n*, but not so close but that the point of the pallet may pass by the hooked end of the spring E F without touching it; the head of the adjusting-screw *m* is also supposed to bear gently on the inner side of the said spring E F, or that nearest to the wheel, and at the same time the locking-pallet is so placed, that one of the teeth, D, of the balance-wheel, may just take hold of it. This pallet is not visible in its proper place in the figure, being covered from sight by the screw *m*, and part of the spring E F; its position is therefore represented by the dot *k*, on the opposite side of the wheel, having the tooth A just bearing

up against it. From the above description of the several parts of the escapement, and their connection with each other, it will be easy to see the mode of its action, which it as follows:

A force being supposed to be applied to the balance-wheel, so as to cause it to move round in the direction of the letters A B C D, one of the teeth, as D, will come against the locking-pallet, (as represented at A, and the locking pallet by *k*.) The wheel is then said to be locked, being prevented from being moved forward by this pin. Let the balance be now supposed to rest in its quiescent position, and it will have the situation represented in the figure; the lifting point *i* of the pallet *i n* will be just clear of the projecting end of the slender spring, the face, *h l*, of the large pallet M S K will fall a little below the point of the tooth B, and the balance, having its spiral or helical, (meaning cylindrical,) spring applied to it, remains perfectly at rest in this position. Now, as the balance, and the two pallets M S K and *i n*, are fixed to the verge, it is plain they must all move together; let, therefore, the balance be carried a little way round in the direction of the letters M S K: by this motion, the end *i* of the lifting pallet *i n* will be brought to press up against the projecting end of the slender spring, and as this spring is fixed on the side of the spring E F, nearest to the balance-wheel, the point *i* will press the two springs together out of the balance-wheels; then, as only the point of the tooth D, (see its position at *k*,) touches the locking-pallet when the spring E F was at rest against the head of the screw *m*, it will, by the spring being pressed out from the tooth, have slipped off; (for the locking-pallet, which was before supposed at *k*, will now be at *a*, clear of the tooth A of the balance-wheel;) the wheel being now at liberty, will move round by the force supposed to be applied to it; but as the point *i* of the lifting-pallet moves on and presses out the spring, the point, *l*, of the large pallet approaches towards the point of the tooth B of the balance-wheel, so that when the spring E F is sufficiently pushed out to unlock the wheel, the point *l* of the large pallet will be got to *d*, and in this position the point of the tooth B of the balance-wheel will fall upon it, at the same time the point of the tooth D has just dropped off from the locking-pallet *m*; the force of the wheel, being by this means applied to the top of the pallet *h l*, gives an increased momentum to the balance, and assists it in its motion in the same direction, and by the continued motion of the large pallet in the direction M S K, the point of the tooth B, which keeps pressing and urging it forward, moves up towards the bottom of the face of the pallet towards *h*, until the plain flat surfaces of the tooth and pallet come into contact; by this time the end *o* of the slender spring has dropped off from the point *i* of the lifting-pallet, and the two springs have returned again into their quiescent position, the spring E F gently bearing against the head of the adjusting screw, *m*, and the locking-pallet, in a position to receive the next tooth, C, of the balance-wheel. When the two surfaces of the tooth and pallet are thus in contact, the greatest force of the wheel is exerted upon the pallet, and of course upon the balance moving with it. The tooth still pressing against the face of the pallet, and the pallet moving in the direction M S K, it at last drops off, leaving the balance at perfect liberty to move on in the same direction in which it was going. Just as the point of the tooth B, which has been pressing the large pallet round, is ready to leave it, the next tooth, C, of the wheel is almost in contact with the locking-pallet *m*, so that the instant the tooth B drops off, the wheel is again locked, and the action of that tooth on the balance is finished. As the balance moves with the greatest freedom upon its pivots, the force of the tooth has given it a considerable velocity, so that the balance still keeps moving on in the same direction, after the pressure of the tooth is removed by slipping

off from the pallet, until the force of the pendulum-spring, (which is not represented in the figure,) being continually increased by being wound up, overcomes the momentum of the balance, which for an instant of time is then stationary, but immediately returns by the action of the pendulum spring, which exerts a considerable force upon it in unwinding itself. As the balance returns, the point *i*, of the lifting-pallet *i n*, passes by the ends of two springs, E F and Y O, and, in passing by, pushes the projecting end *o* of the slender spring in towards the balance-wheel, until it has passed it; after this, the projecting end *o* again returns, and applies itself close to the hooked end of the spring E F as before. The spring *y o* is made so slender that it gives but little resistance to the balance, during the time the point *i* of the lifting-pallet is passing it, and of course causes but little, if any, decrease in its momentum. During the time the point *i* of the lifting-pallet is passing in the small spring *y o*, the long spring E F remains steadily bearing against the head of the adjusting-screw *m*, as the hooked end at *o* just lets the end of the lifting-pallet pass by without touching it. As the spring has now been continually acting upon the balance, from the extremity of its vibration, in the direction M S K, it has given it the greatest velocity when the point *i* of the lifting-pallet is passing the end *o* of the slender spring; for at this instant the spring which was wound up by the contrary direction of the balance, is now unwound again, or in the same state as it was in its quiescent position at first, and of course has no effect at all upon the balance in either direction; but the balance, having now all the velocity it would acquire from the unwinding the spring, goes on in the direction S M K until the force of this spring again stops it, and brings it back again, moving in the same direction as at first, with a considerable velocity. By this return of the balance, the point *i* of the lifting-pallet comes up again to the projecting end *o* of the slender spring, pushes back the long spring E F, and unlocks the wheel; and another tooth falling upon the face of the pallet *h l*, gives fresh energy to the balance; and thus the action is carried on as before.

ESCAPEMENT, OR 'SCAPEMENT.

The motions of a clock or watch are regulated by a pendulum or balance, which serves as a check, without which, the wheels impelled by the weight in the clock, or spring in the watch, would run round with a rapidly accelerating motion, till this should be rendered uniform by friction, and the resistance of the air; if, however, a pendulum or balance be put in the way of this motion, in such manner that only one tooth of a wheel can pass, the revolutions of the wheel will depend on the vibration of the pendulum or balance.

We know that the motion of the pendulum or balance is alternate, while the pressure of the wheels is constantly exerted in the same direction. Hence it is evident that some means must be employed to accommodate these different motions to each other. Now, when a tooth of the wheel has given the pendulum or balance a motion in one direction, it must quit it, that the pendulum or balance may receive an impulsion in the opposite direction. This *escaping* of the tooth has given rise to the term *escapement*.

The ordinary 'scapement is extremely simple, and may be thus illustrated Let *x y*, fig. 523, represent a horizontal axis, to which the pendulum is attached by a slender rod. This axis has two leaves, *c* and *d*, one near each end, and not in the same plane, but so that when the pendulum hangs perpendicularly at rest, *c* spreads a few degrees to the right, and *d* as much to the left. These are called the pallets. Let *a f b* represent a wheel, turning on a perpendicular axis, *e o*, in the order *a f e b*. The teeth of this wheel are in the form of those of a saw, leaning forward in the direction of the rim's motion. This wheel is usually called the *crown-wheel*, or in watches the *balance-wheel*. It in general contains an odd number of teeth. In the figure the pendulum is represented at the extremity of its excursion towards the right, the tooth *a* having just escaped from the pallet *c*, and *b* having just dropped on *d*.

Now it is evident, that while the pendulum is moving to the left, in the arc *p g*, the tooth *b* still presses on the pallet *d*, and thus accelerates the pendulum, both in its descent along *p h*, and its ascent up *h g*, and that when *d*, by turning round the axis *x y*, raises its point above the plane of the wheel, the tooth *b* escapes from it, and *i* drops on *c*, now nearly perpendicular. Thus *c* is pressed to the right, and the motion of the pendulum along *g p* is accelerated. Again, while the pendulum hangs perpendicularly in the line *x h*, the tooth *b*, by pressing on *d*, will force the pendulum to the left, in proportion to its lightness, and if it be not too heavy, will force it so far from the perpendicular, that *b* will escape, and *i* will catch on *c*, and force the pendulum back to *p*, when the same motion will be repeated. This effect will be the more remarkable if the rod of the pendulum be continued through *x y*, and have a ball *q*, on the other end, to balance *p*.

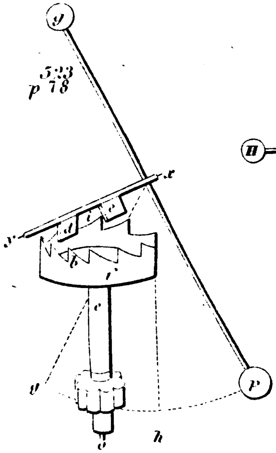
When *b* escapes from *d*, the balls are moving with a certain velocity and momentum, and in this condition the balance is checked when *i* catches on *c*. It is not, however, instantly stopped, but continues to move a little to the left, and *i* is forced a little backward by the pallet *c*. It cannot make its escape over the top of the tooth *i*, as all the momentum of the balance was generated by the force of *b*, and *i* is of equal power. Besides, when *i* catches on *c*, and the motion of *c*, to the left, continues, the lower point of *c* is applied to the face of *i*, which now acts on the balance by a long lever, and soon stops its motion in that direction, and, continuing to press on *c*, urges the balance in the opposite direction. In this, it is evident that the motion of the wheel is hobbling and unequal, by which this escapement has received the appellation of the *recoiling 'scapement*.

In considering the utility of the following improved 'scapement for clocks, we must keep in mind the following proposition, which, after the above illustration, scarcely requires any proof. It is, that the natural vibrations of a pendulum are *isochronous*, or are performed in equal times. The great object of the 'scapement is to preserve this isochronous motion of the pendulum.

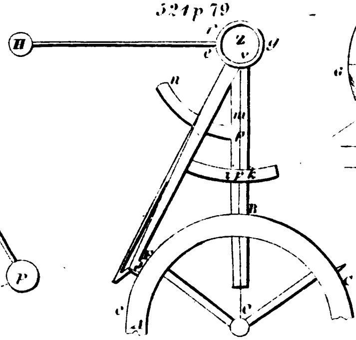
As the defect of the recoiling 'scapement was long apparent, several ingenious artists attempted to substitute in its place a 'scapement that should produce a more regular and uniform motion. Of these, the 'scapement contrived by Mr Cumming appears to be one of the most ingenious in its construction, and most perfect in its operation. The follow-

*From 523 to 527 **

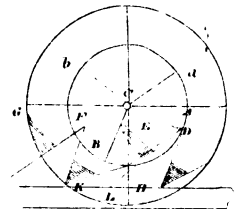
523 p 78



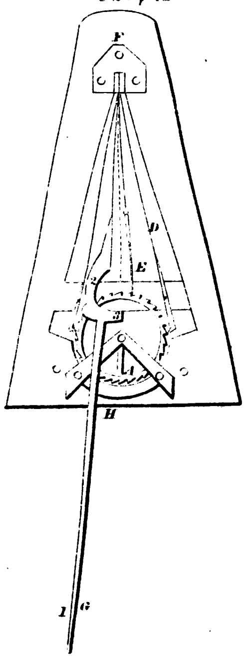
524 p 79



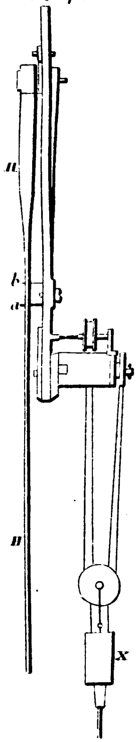
525 p 80



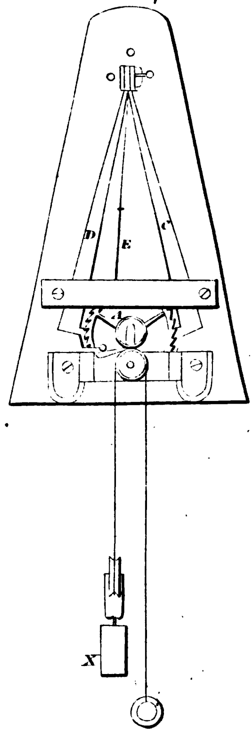
526 p 81



527 p 81



527 p* 81



ing construction is similar to that of Mr Cumming, but rendered rather less complex for the purpose of shortening the description.

Let A B C, fig. 524, represent a portion of the swing-wheel, of which O is the centre, and A one of the teeth, and Z the centre of the crutch, the pallets, and pendulum. The crutch is represented of the form of the letter A, having in the circular cross-piece a slit *i k*, which is also circular, Z being the centre. The arm Z F forms the first detent, and the tooth A is represented as locked on it at F. D is the first pallet on the end of the arm Z *d*, movable round the same centre with the detents, but independent of them. The arm, *d e*, to which the pallet D is attached, lies wholly behind the arm Z F of the detent, being fixed to a round piece of brass, *e f g*, having pivots turning concentric with the axis of the pendulum. To the same piece of brass is fixed the horizontal arm *e* H, carrying at its extremity the ball H, of such size that the action of the tooth A on the pallet D is just able to raise it up to the position represented. Z P *p* represents the fork, or pendulum-rod, behind both detent and pallet. A pin *p* projects forward, coming through the slit *i k*, without touching either margin of it. Attached to the fork is the arm *m n*, of such length that, when the pendulum-rod is perpendicular, the angular distance of *n q* from the rod *e q* H is just equal to the angular distance of the left side of the pin *p* from the left end *i* of the slit *i k*.

Now the natural position of the pallet D is at *δ*, represented by the dotted lines, resting on the back of the detent F. It is naturally brought into this position by its own weight, and still more by the weight of the ball H. The pallet D, being set on the foreside of the arm at Z, comes into the same plane with the detent F and the swing-wheel, though represented in the figure in a different position. The tooth C of the wheel is supposed to have escaped from the second pallet, on which the tooth A immediately seizes the pallet D, situated at *δ*, forces it out, and then rests on the detent F, the pallet D leaning on the tip of the tooth. After the escape of C, the pendulum, moving down the arch of semi-vibration, is represented as having attained the vertical position. Proceeding still to the left, the pin *p* reaches the extremity *i* of the slit *i k*; and, at the same instant, the arm *n* touches the rod *e* H in *q*. The pendulum proceeding a hair's-breadth further, withdraws the detent F from the tooth, which now pushes off the detent, by acting on the inclining face of it.

The wheel being now unlocked, the tooth, following C on the other side, acts on its pallet, pushes it off, and rests on its detent, which has been rapidly brought into a proper position by the action of A on the inclined face of F. By a similar action of C on its detent at the moment of escape, F was brought into a position proper for the wheels being locked by the tooth A. As the pendulum still goes on, the ball H, and pallet connected with it, are carried by the arm *m n*, and before the pin *p* again reaches the end of the slit, which had been suddenly withdrawn by the action of A on F, the pendulum comes to rest. It now returns towards the right, loaded with the ball H on the left, and thus the motion lost during the last vibration is restored. When the pin *p*, by its motion to the right, reaches the end *k* of *i k*, the wheel on the right side is unlocked, and at the same instant the weight H, being raised from the the pendulum by the action of a tooth like B on the pallet D, ceases to act.

In this 'scapement, both pallets and detents are detached from the pendulum, except in the moment of unlocking the wheel, so that, excepting during this short interval, the pen-

dulum may be said to be free during its whole vibration, and of course its motion must be more equable and undisturbed.

The constructing of a proper 'scapement for watches requires peculiar delicacy, owing to the small size of the machine, from which the error of $\frac{1}{100}$ of an inch has as much effect as the error of a whole inch in a common clock. From the necessary lightness of the balance too, it is extremely difficult to accumulate a sufficient quantity of regulating power. This can only be done by giving the balance a great velocity, which is effected by concentrating as much as possible of its weight in the rim, and making its vibrations very wide. The balance-rim of a tolerable watch should pass through at least ten inches in every second.

In considering the most proper 'scapements for watches, we may assume the following principle; viz. that the oscillations of a balance urged by its spring, and undisturbed by extraneous forces, are isochronous.

In ordinary pocket-watches, the common recoiling 'scapement of clocks is still employed, and answers the common purposes of a watch tolerably well, so that, if properly executed, a good ordinary watch will keep time within a minute in the day. These watches, however, are subject to great variation in their rate of going, from any change in the power of the wheels.

The following is considered as the best construction of the common watch 'scapement, and is represented by fig. 525, as it appears when looking straight down on the end of the balance-arbor. C marks the centre of the balance and verge; C A represents the upper pallet, or that next the balance, and C B the lower pallet; F and D are two teeth of the crown-wheel, moving from left to right; E G are two teeth in the lower part, moving from right to left. The tooth D appears as having just escaped from the point of C A, and the tooth E as having just come in contact with C B. In practice, the 'scapement should not be quite so close, as, by a small inequality of the teeth, D might be kept from escaping at all. In the best proportioned watches, the distance between the front of the teeth, that is, of G F E D, and the axis C of the balance, is one-fifth of F A, the distance between the points of the teeth. The length C A, C B, of the pallets is three-fifths of the same degrees, and the front D H, or F K of the teeth makes an angle of 25° with the axis of the crown-wheel. The sloping side of the tooth must be of an epicycloidal form, suited to the relative motion of the tooth and pallet.

It appears from these proportions, that by the action of the tooth D, the pallet A can throw out till it reach a, 120° from C L, the line of the crown-wheel axis. To this we add B C A = 95°, we shall have L C a = 120°. Again, B will throw out as far on the other side. Now, if from 240°, the sum of the extent of vibration of both pallets, we take 95°, the angle of the pallets, the remainder 145° will express the greatest vibration which the balance can make without striking the front of the teeth. From several causes, however, this measure is too great, and 120° is reckoned a sufficient vibration in the best ordinary 'scapement. *Encyclopædia Britannica.*

In 1812, Mr Prior, jun. was rewarded by the Society of Arts for the construction of a remontoire escape which possesses considerable merit.

The advantage of this escapement is such as will give an exact and equal impulse to the pendulum without any friction, and which cannot be at all affected by any irregularities or variations arising by the clogging of oil and increasing of friction from the train, except during the very small part of the vibration that the pendulum is removing the spring detents from off the points of the teeth of the escape-wheel, the effect of which can never be discovered in the rate by any variation the oil on the pivots and the increase of friction can ever produce, as long as the wheels will be able to wind up the renovating spring, which will be nearly as long as they can move at all, as the renovating spring has not either to be wound up quick, or to be pushed beyond any catch or spring to keep it in its proper situation, nor can there ever be any increase of friction in winding up the renovating spring, as it is formed in nearly as right a line as possible; consequently must go almost endlessly without cleaning, and will never require any oil.

The swing-wheel A, figs 526 and 527*, has thirty teeth cut in its periphery, and is constantly urged forward by the maintaining power, which is supplied by a small weight X, figs. 527 and 527*; C D are two spring detents catching the teeth of the wheel alternately, these are, at the proper intervals, unlocked by the parts marked 2 and 3, fig. 526, upon the pendulum rod H, intercepting small pins *a b*, fig. 527, projecting from the detents, as it vibrates towards the one or the other; E is the renovating or remontoire spring, fixed to the same stud F, as the detents; it is wound up by the highest tooth of the wheel, as seen in fig. 526, (its position when unwound being shown by the dotted line.) This being a case, suppose a tooth of the wheel is caught by the detent E, which prevents the wheel from moving any further, and keeps the renovating spring from escaping off the point of the tooth; in this position, the pendulum is quite detached from the wheel; now, if the pendulum be caused to vibrate towards G, the part of it marked 2 comes against the pin *b*, fig. 527, projecting from the renovating spring E, and pushes this spring from the point of the wheel's tooth; on vibrating a little further, it removes the detent D, which detained the wheel, by the part 3 striking the pin *a*, fig. 2, which projects from the detent; the maintaining power of the clock causes the wheel, thus unlocked, to advance, until detained by a tooth resting upon the end of the detent C, on the opposite side; by this means the renovating spring will be clear of the tooth of the wheel as it returns with the pendulum, and gives it an impulse, by its pin *b* pressing against the part 2 of the pendulum, until the spring comes to the position shown by the dotted line, in which position it is unwound, and rests against the pin fixed in the cross bar of the plate; the pendulum continues vibrating towards I, nearly to the extent of its vibration, when the part 1 meets the pin in the detent C, and removes it from the wheel, and unlocks it; the maintaining power now carries it forward, pushing the renovating spring E before it, until another tooth is caught by

the detent D, which detains the wheel in the position first described, the renovating spring being wound up ready to give another impulse of the pendulum.

The pin *b*, fig. 527, is not fixed to the renovating spring itself, but is part of a piece of brass, which is screwed fast to the renovating spring, and is made very slender near the screw which fastens it; this permits the renovating spring to give way, if, by the weight being taken off the clock, or any other accident, the escape-wheel should be wound backwards, so as to catch on the detents improperly.

In this escapement it is necessary to attend to the following observations:

1st. That the renovating and detent springs must spring from one centre, and as similarly as possible.

2dly. That the force applied to the train must be so much more than what will wind up the renovating spring, as will overcome the influence of oil and friction on the pivots of the machine.

3dly. That the renovating spring, when unwound, must rest against the point of the tooth of the wheel, which will be an advantage, as it thereby takes as much force off the tooth of the wheel resting against the detent spring as is equal to the pressure of the renovating spring C, against the face of the tooth of the wheel.

4thly. The detent springs must be made as slender and light as possible, though whatever force they take from the pendulum by their elasticity in removing them to unlock the wheel, so much force they return to the pendulum in following it, to where it removed them from, therefore action and reaction will be equal in contrary directions.

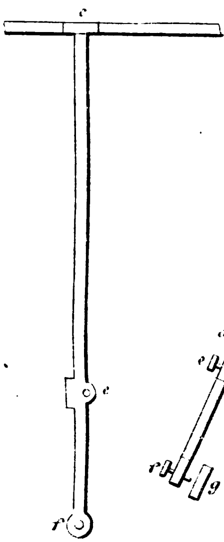
5thly. That it is necessary for the pendulum to remove the detents or renovating springs, much further than it is necessary to free the teeth of the wheel, as it will always vibrate on the same arc; in table clocks it ought to remove them further, so that it can go when not placed exactly level, or what is generally termed out of the beat.

The following description of a clock escapement, contrived by Mr Reid, about twelve or fifteen years ago, is extracted from the Edinburgh Encyclopædia:

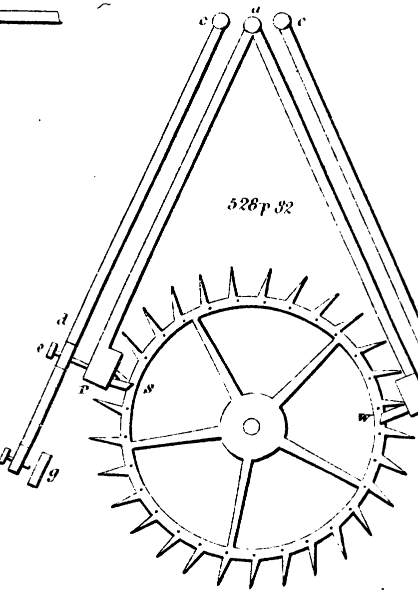
Fig. 528. S W is the swing-wheel, whose diameter may be so large as to be sufficiently free of the arbor of the wheel that runs into its pinion, which in eight-day clocks is the third. The teeth of this swing-wheel are cut thus deep, in order that the wheel may be as light as possible, and the strength of the teeth little more than what is necessary to resist the action or force of a common clock weight through the wheels. They are what may be called the locking-teeth, as will be more readily seen from the use of them afterwards to be explained. Those called the impulse-teeth, consist of very small tempered steel pins, inserted on the surface of the rim of the wheel on one side only. They are nearly two-tenths of an inch in height; and the

From 528 to 536.

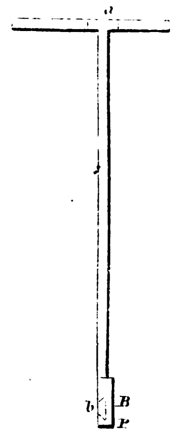
530 p 83



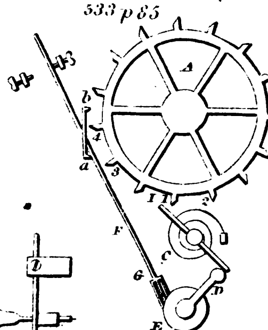
528 p 82



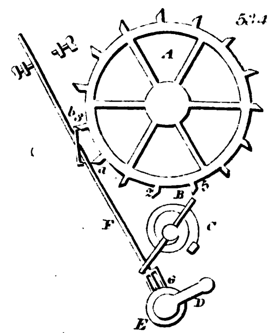
529 p 83



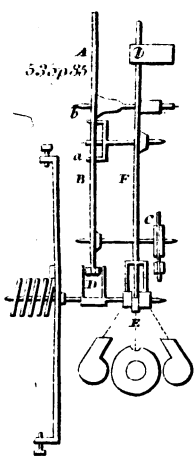
533 p 85



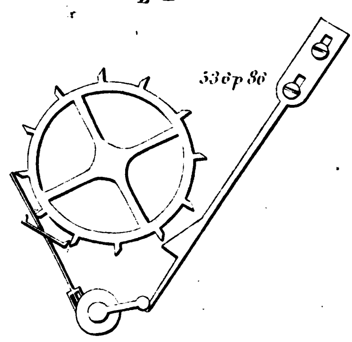
534 p 85



535 p 85



536 p 86



smaller they are so much more room will be given for the thickness of the pallets. If they have strength to support about 80 or 100 grains, they will be strong enough. There is no rule required for placing them relatively to the locking-teeth, only they may as well be opposite to these teeth as any where else. P P are the pallets whose centre of motion is the same as that at the verge at *a*. These pallets are formed so as to have the arms sufficiently strong, and at the same time as light as may be. That part where the arms meet at the angle at *a*, has a steel socket made out of the same piece as the arms, being forged together in this manner. The socket is made to fit well on the verge, on which it is only twisted fast, and is turned pretty small on the outside, in order to allow the arbors of the detents to be laid as close to the verge as may be, so that their centres of motion may coincide as nearly as possible. A perfect coincidence of the centres might be obtained by using a hollow cylinder for the verge, with the detent-arbors running inside of it, but this would have occasioned more trouble. That part of the pallet frame, as it may be called, in which is set the stone for receiving the action or impulse of the small pin teeth, is formed into a rectangular shape, so as to allow room for a dove-tail groove, into which the stone pallets are fixed, as may be seen at P P, fig. 528, and P, fig. 529, which also gives a side view of the verge at *a*, and where the socket of the pallets is seen as fixed on the verge. At B, fig. 529, is seen the outer end of one of the stone pallets made flush with the steel. That part of the stone pallets upon which the pin teeth act may be seen in fig. 528, where they are represented in their respective positions relative to the pin teeth. Their shape or form is exactly that which gives the dead beat. In fig. 528 are seen the detents *d d*, whose centre of motion is at *c c*. They are fixed on their arbors by a thin steel socket, made as forged with the detents, much in the same way as the pallets were, as may be seen at *c*, fig. 530, which gives a side view of one of the detents and its arbor. The screws *e e*, *f f*, in the arms of the detents, have a place made to receive them, which is more readily seen in fig. 530 than in fig. 528. The screws *e e* serve for the purpose of adjusting that part of the 'scapement connected with the pallets pushing the detents out from locking the wheel, by means of locking the teeth. The ends of the screws *e e*, on the unlocking, are met by the ends of the stone pallets, one of which is represented at *b*, fig. 529. The screws *f f* seem to adjust the locking of the wheel-teeth on the detents; *g g* are brass rectangular pieces, or studs, which are fixed to the inside of the pillar frame plate, and may be near an inch high. The ends of the screws *f f* rest on the side of these studs, and according as they are more or less screwed through at the ends of the detents, so much less or more hold will the detent piece have of the teeth. These holding pieces of the detents are not represented in the drawing, as they would have made other parts of it rather obscure. They are made of stone, and are fitted in by means of a dove-tail cut in a piece left for that purpose, on the inside of the detent-arms, as may easily be conceived from the drawing, where it is represented in part at *e*, fig. 530; and is in the line across the arm with the screw, *e*, which is close by the edge of the detent-stone piece, which projects a little beyond the end of the screw. Having described the parts of the 'scapement, we shall now explain their mode of action. On the left-hand side the pin tooth is represented as having just escaped its pallet, as seen in fig. 528; but previous to its having got on to the flanch of this pallet, let us conceive that the back of the pallet, or end piece *b* of it, had come, in consequence of the motion of the pendulum, to that side, and opposing the screw *e*, which is in the detent-arm, pushes or carries it on with it, and consequently unlocks the tooth of the wheel, which then endeavours to get forward, but the pin tooth at this instant of unlocking, meeting with the flanch of the pallet at the lower edge inside, and pushing forward on the flanch, by this means im-

pels the pendulum, and after having escaped the pallet, the next locking tooth is received by the detent, on the right-hand side, where the wheel is now again locked. In the mean time, while the pendulum is describing that part of its vibration towards the left hand free and detached, as the pallets are now at liberty to move freely and independently of the small pin teeth, on the return of the pendulum to the right-hand side, the detent, by means of the pallet on that side, is pushed out from locking the wheel, and at the instant of unlocking, the wheel gets forward, and the pin tooth is at the same instant ready to get on the flanch of its pallet, and gives new impulse to the pendulum, as is obvious by what is represented in the drawing, fig. 528. After the pin tooth has escaped the pallet, the wheel is again locked on the opposite or left-hand side; the pendulum moves on to the right freely and independently till the next locking on the left takes place, and so on. It may be observed, that the unlocking takes place when the pendulum is near the lowest point, or point of rest, and of course where its force is nearly a maximum.

Without attaching any thing to the merits of this 'scapement, we may remark that the clock was observed from time to time by a very good transit instrument, and, during a period of eighty-three days, it kept within the second, without any interim apparent deviation. This degree of time-keeping seemed to be as much a matter of accident as otherwise; and cannot reasonably be expected from this or any other clock as a fixed or settled rate.

This 'scapement being a detached or free 'scapement, can at pleasure be converted into a recoiling or dead beat one, without so much as once disturbing or stopping the pendulum a single vibration. To make dead beat of it, put in a peg of wood, or small wire, to each, so as to raise the detents free of the pallets; and these being left so as to keep them in the position, the pin teeth will now fall on the circular parts of the pallets, and so on to the flanch, and the 'scapement is then, to all intents and purposes, a dead beat one. To make a recoiling one of it, let there be fixed to each arbor of the detents, a wire to project horizontally from them about 3½ or 4 inches long; the outer ends of the wires must be tapped about half an inch in length; provide two small brass balls, half an ounce weight each, having a hole through them, and tapped so as to screw on the wires; the balls can be put more or less home, and be adjusted proportionably to the force of the clock on the pendulum. No recoil will be seen on the seconds' hand; yet these will alternately oppose and assist the motion of the pendulum, as much as any recoiling pallets can possibly do; and as their efforts on the pendulum will be exactly the same, it may be considered as a good recoiling 'scapement. This sort of detatched 'scapement, by becoming a dead beat, or a recoiling one, at any time when

required, makes it convenient for making various experiments with the different 'scapements.

Another 'scapement, in which a considerable degree of ingenuity is united with comparative simplicity, is that of Mr De Lafons. The inventor's description, and some of his observations, as presented to the Society of Arts, are as follows:

"Although the giving of an equal impulse to the balance has been already most ingeniously done by Mr Mudge and Mr Haley, (from whose great merit I would not wish to detract,) yet the extreme difficulty and expense attending the first, and the very compound locking of the second, render them far from completing the desired object.

"The perfections and advantages arising from my improvements on the remontoire detached 'scapement for chronometers, which gives a perfectly equal impulse to the balance, and not only entirely removes whatever irregularities arise from the different states of fluidity in the oil, from the train of wheels, or from the mainspring, but does it in a simpler way than any with which I am acquainted. I trust it will not be thought improper in me to answer some objections made at the examinations before the committee, as I am fully persuaded the more mathematically and critically the improvements are investigated, the more perfect they will prove to be.

"It was first observed that my method did not so completely detach the train of wheels from the balance as another 'scapement then referred to. I beg leave to remark, that the train of wheels in mine is prevented from pressing against the locking by the whole power of the remontoire-spring; so that the balance has only to remove the small remaining pressure, which does away the objection, and also that of the disadvantage of detents, as this locking may be compared to a light balance turning on fine pivots, without a pendulum-spring; and has only the advantage of banking safe at two turns of the balance, and of being firmer, and less liable to be out of repair, than any locking where spring-work is used, but likewise of unlocking with much less power. It was then observed, it required more power to make it go than usual. Permit me to say, it requires no more power than any other remontoire-scapement, as the power is applied in the most mechanical manner possible. And, lastly, it was said, that it set or required the balance to vibrate an unusually large arch before the piece would go. This depends on the accuracy of the execution, the proportionate diameter and weight of the balance, the strength of the remontoire-spring, and the length of the pallets. If these circumstances are well attended to, it will set but little more than the most generally detached 'scapements."

A shows the scape-wheel, fig. 534.

B, the lever-pallet, or an arbor with fine pivots, having at the lower end,

C, the remontoire or spiral-spring fixed with a collar and stud, as pendulum-springs are.

D, the pallet of the verge, having a roller turning in small pivots for the lever-pallet to act against.

E, pallets to discharge the locking, with a roller between, as in fig. 535.

F, the arm of the locking-pallet continued at the other end to make it poise, having studs and screws to adjust the bank and quantity of motion.

a and *b*, the locking-pallets, being portions of circles, fastened on an arbor turning on fine pivots.

G, the triple fork, at the end of the arm of the locking-pallets.

"The centre of the lever-pallet in the draft, is in a right line between the centre of the scape-wheel and the centre of the verge, though in the model it is not: but may be so or not, as best suits the calliper, &c.

"The scape-wheel A, with the tooth 1, is acting on the lever-pallet B, and has wound up the spring C; the verge pallet D, (turning the way represented by the arrow,) the moment it comes within the reach of the lever-pallet, the discharging pallet E, taking hold of one prong of the fork, removes the arm F, and relieves the tooth 3 from the convex part of the lock *a*. The wheel goes forward a little, just sufficient to permit the lever-pallet to pass, while the other end gives the impulse to the balance: the tooth 4 of the wheel is then locked on the concave side of the lock *b*, and the lever-pallet is stopped against the tooth 5, as in fig. 536. So far the operation of giving the impulse, in order again to wind the remontoire-spring, (the other pallet at E, in the return, removing the arm F the contrary direction,) relieves the tooth 3 from the lock *b*. The wheel again goes forward, almost the whole space, from tooth to tooth, winds the spiral-spring again, and comes into the situation of fig. 534, and thus the whole performance is completed. The end of the lower pallet B resting on the point of the tooth 1, prevents the wheel exerting its full force on the lock *a*, as in fig. 534. The same effect is produced by the pallet lying on the tooth 5, by preventing the wheel from pressing on *b*; and thus the locking becomes the tightest possible. This 'scapement may be much simplified by putting a spring with a pallet made in it, as in fig. 534, instead of the lever pallet and spiral-spring. The operation will be in other respects exactly the same, avoiding the friction of the pivots of the lever-pallet. This method I prefer for a piece to be in a state of rest, as a clock; but the disadvantage, from the weight of the spring in different positions, is obvious. The locking may be on any two teeth of the wheel, as may be found most convenient.

PENDULUMS.

The pendulum is a simple ponderous body, so suspended, that it may swing backwards and forwards, about some fixed point, by the mere force of gravity.

These alternate ascents and descents of the pendulum are called its *oscillations*, or *vibrations*; each oscillation being the arc which the pendulum describes from the highest point on one side to the highest point to the other side. The point round which the pendulum moves, or vibrates, is called the *axis of suspension*, or *centre of motion*; and a right line drawn through the centre of motion, parallel to the horizon, and perpendicular to the plane in which the pendulum moves, is called the *axis of oscillation*. There is also a certain point within every pendulum, into which, if all the matter that composes the pendulum were collected, or condensed, as into a point, the times in which the vibrations would be performed would not be altered by such condensation; and this point is called the *centre of oscillation*. The length of the pendulum is always estimated by the distance of this point below the centre of motion, being usually near the bottom of the pen-

dulum; but in a slender cylinder, or any other uniform prism or rod suspended at the top, it is at the distance of one-third from the bottom, or two-thirds below the centre of motion.

The length of a pendulum, so measured to its centre of oscillation that it will perform each vibration in a second of time, thence called the seconds' pendulum, has, in the latitude of London, been generally taken at $39\frac{2}{10}$ or $39\frac{1}{5}$ inches; but by some very ingenious and accurate experiments, the late celebrated Mr George Graham found the true length to be $39\frac{128}{1000}$ inches, or $39\frac{1}{8}$ inches very nearly.

The length of the pendulum vibrating seconds at Paris was found by Varin, Des Hays, De Glos, and Godin, to be $440\frac{5}{6}$ lines; by Picard, $440\frac{1}{2}$ lines; and by Mairan, $440\frac{17}{30}$ lines.

As all woods and metals are more or less affected by changes of temperature, many ingenious contrivances have been resorted to, to counteract the effects of heat and cold, in lengthening or shortening a pendulum-rod.

The first person who observed that, by change of temperature, metals changed their length, was Godfroi Wendelinus; and he who first endeavoured to take advantage of this knowledge, to counteract the effects of heat and cold upon a pendulum, was Graham, who, in the year 1715, suggested that a combination of rods or wires of different metals would have a tendency to that effect; but being of opinion that this would not be quite adequate to the desired purpose, he did never, we believe, put it in execution. Still continuing his observations, he, a short time afterwards, conceived that mercury, from its great expansion by heat, was more adapted to the end he was pursuing, and accordingly we find, that, by the 9th of June 1722, he had constructed a clock which had a pendulum upon this principle, and which he kept continually going, without having either the pendulum or the hands altered, for the space of three years and four months, during which he found the errors of his were but about one-eighth part of those of one of the best sort of common clocks, with which he had compared it. This pendulum, which is called the *mercurial pendulum*, consists of a rod of brass, branched towards the lower end, so as to embrace a cylindric glass jar 13 or 14 inches long, and about two inches diameter; which, being filled about 12 inches deep with mercury, forms the weight or ball of the pendulum. In adjusting this pendulum, if the expansion of the rod be too great for that of the mercury, more mercury must be poured into the vessel; but if the expansion of the mercury exceed that of the rod, so as to occasion the clock to go fast with heat, some of the mercury

must be taken out, to shorten the column. This pendulum though troublesome to construct, because any filling in or taking out of the mercury from the cylinder or glass jar, to bring about the compensation, will cause a change of place in the index-point on the graduated arch or index-plate, if such a thing be used, is, notwithstanding some defect may arise from the expansion of the mercury commencing sooner than that of the rod, of much practical excellence. The mercurial pendulum has been much improved by Reid; for an account of which we must refer our readers to the article "Horology," written by this gentleman, and inserted in the *Edinburgh Encyclopædia.*

Mr Harrison, of whom we have already spoken under the article Chronometers, some time previous to 1726, constructed a pendulum in which the compensation was effected by the opposite contraction of different metals. This pendulum, called the *gridiron-pendulum*, from, we suppose, its bearing a near resemblance to the culinary implement of that name, was made of five steel and four brass rods, placed in alternate order, the middle rod, by which the pendulum-ball is suspended, being of steel. These rods are so connected with each other at their ends, that while the expansion of the steel rods has a tendency to lengthen the pendulum, the expansion of the brass rods, acting upwards, tends to shorten it, so that by the combined effect the pendulum is invariably preserved of the same length. This is a very ingenious and simple contrivance, and the only objections we have heard urged against this mode of compensation are, 1st, the difficulty of exactly adjusting the length of the rods; 2dly, of proportioning their thickness, so that they shall all begin to contract or expand at the same instant; 3dly, the connecting bars of a pendulum thus constructed are apt to move by starts; 4thly, this kind of pendulum is more exposed to the air's resistance than a simple pendulum.

Other modes of constructing pendulums on the principle of the opposite contraction of metals have been contrived by other ingenious artists, among whom we may notice Ellicott, Cumming, Troughton, Reid, and Ward.

In Ellicott's pendulum the ball was adjustable by levers, thence called the *lever-pendulum*, which can never be equal to those in which the expansion and contraction act by contact in the direct line of the pendulum-rod; the construction nevertheless evinced great ingenuity. The rod of this pendulum was composed of two bars, one of brass, and the other of steel. It had two levers, each sustaining its half of the

ball or weight, with a spring under the lower part of the ball to relieve the levers from a considerable part of its weight, and so to render their motion more smooth and easy. These levers were placed within the ball, and each had an adjusting screw to lengthen or shorten the lever, so as to render the adjustment the more perfect. See the *Philos. Transact.* vol. xlvii. p. 479; where Mr Ellicott's methods of construction are described and illustrated by figures.

This pendulum was much improved by Cumming, who conceived that where there were two bars only, a flexure and unequal bearing would take place, and consequently an exact compensation could not be effected. To remedy this, he constructed a pendulum of one flat bar of brass, and two bars of steel, and used three levers within the ball of the pendulum, whereas Mr Ellicott used only two. Among many other ingenious contrivances for the more accurate adjusting of this pendulum to mean time, it is provided with a small ball and screw below the principal ball or weight, one entire revolution of which on its screw will only alter the rate of the clock's going one second per day; and its circumference is divided into 30, one of which divisions will therefore alter its rate of going one second in a month.

Troughton's *tubular-pendulum*, which acts on the principle of the gridiron-pendulum, is a very neat and ingenious contrivance. It is constructed of an exterior tube of brass, reaching from the bob nearly to the top, within which is another tube, and five brass wires in its belly, so disposed as to produce altogether, (like Harrison's gridiron-pendulum,) three expansions of steel downwards, and two of brass upwards, whose lengths being inversely proportioned to their dilatation, when properly combined, destroy the whole effect that either metal would have singly. The small visible part of the rod, near the top, is a brass tube, whose use is to cover the upper end of the middle wire, which is single, and otherwise unsupported. Drawings of this pendulum may be seen in *Nicholson's Journal*, No. 36, N. S.

Reid's pendulum is composed of a zinc tube, and three long and one short steel rods, connected by means of traverses. Two of these long rods are inserted at one end in the ball of the pendulum, and terminate at the other in the upper traverse, which keeps them exactly parallel with respect to each other. At the lower ends of these rods, not far above the ball, is another traverse, in the middle of which the short steel rod is pinned, descending thence through the centre of the ball. Another traverse is placed a little above this, on

the centre of which the zinc tube rests, extending upwards, and pressing against, or rather pressed by the upper traverse. The third or centre steel rod passes through a hole in the upper traverse, equidistant from each of the other two steel rods, thence down the zinc tube, and finally is pinned to the second traverse, or that traverse on which the zinc tube rests. By this means, the centre steel rod, when lengthened by heat, will make the lower end of the zinc tube descend with it; but the same cause which lengthens the steel rod downwards will expand the zinc tube upwards, and this will carry up the two outside steel rods with which the ball of the pendulum is connected; their expansion downwards, as well as that of the centre rod, is compensated by the upper expansion of the zinc tube. In constructing a pendulum upon this principle, it would be proper to have a few holes in the tube, for the purpose of admitting air more freely to the centre rod.

Ward's pendulum consists of two flat bars of steel, and one of zinc, connected together by three screws. The description which has been given of it in the Transactions of the Society of Arts, &c. for the year 1807, and the pamphlet which Mr Ward published at Blanford in 1808, contain sufficient details to enable any common clock-maker to copy it.

Before we conclude this article, we shall briefly notice the sympathy or mutual action of the pendulums of clocks.

It is now nearly a century since it was known that when two clocks are set agoing on the same shelf, they will disturb each other; that the pendulum of the one will stop that of the other; and that the pendulum which was stopped will, after a while, resume its vibrations, and in its turn stop that of the other clock, as was observed by the late Mr John Ellicott. When two clocks are placed near one another, in cases very slightly fixed, or when they stand on the thin boards of a floor, it has been long known that they will affect a little the motions of each other's pendulum. Mr Ellicott observed, that two clocks resting against the same rail, which agreed to a second for several days, varied 1′ 36″ in twenty-four hours when separated. The slower having a longer pendulum, set the other in motion in 16⅓ minutes, and stopped itself in 36⅔ minutes.

BUILDING.

Under this general term, which implies the construction of an edifice according to the rules laid down by the different artificers employed, we purpose to treat of the respective business of the Mason, Bricklayer, Carpenter, Joiner, Plasterer, Plumber, Painter, and Glazier; previous to which it will be necessary to consider the sinking of the foundation, the due mixtures of the ingredients which compose the mortar, and the art of making bricks; upon the whole of which materially depends the stability of an edifice.

As firmness of foundation is indispensable, wherever it is intended to erect a building, the earth must be pierced by an iron bar, or struck with a rammer, and if found to shake, must be bored with a well-sinker's implement, in order to ascertain whether the shake be local or general. If the soil is in general good, the loose and soft parts, if not very deep, must be excavated until the labourers arrive at a solid bed capable of sustaining the pier or piers to be built. If not very loose, it may be made good by ramming into it very large stones, packed close together, and of a breadth proportionate to the intended weight of the building; but where very bad it must be piled and planked.

In places where the soil is loose to any great depth, and over which it is intended to place apertures, such as doors, windows, &c. while the parts on which the piers are to stand are firm, the best plan is to turn an inverted arch under each intended aperture, as then the piers in sinking will carry with them the inverted arch, and by compressing the ground compel it to act against the under sides of the arch, which, if closely jointed, so far from yielding, will, with the abutting piers, operate as one solid body; but, on the contrary, if this expedient of the inverted arch is not adopted, the part of the wall under the aperture, being of less height, and consequently of less weight than the piers, will give way to the resistance of the soil acting on its base, and not only injure the brick-work between the apertures, but fracture the window-heads and cills.

In constructing so essential a part as the arch, great attention must be paid to its curvature, and we strongly recommend the parabolic curve to be adopted, as the most effectual for the purpose; but if, in consequence of its depth, this cannot conveniently be introduced, the arch should never be made less than a semi-circle. The bed of the piers should be as uniform as possible, for though the bottom of the trench be very firm, it will in some degree yield to the great weight that is upon it, and if the soil be softer in one part than in another, that part which is the softest, of course will yield more to the pressure, and cause a fracture.

If the solid parts of the trench happen to be under the intended apertures, and the softer parts where piers are wanted, the reverse of the above practice must be resorted to; that is, the piers must be built on the firm parts, and have an arch that is not inverted between them. In performing this, attention must be paid to ascertain whether the pier will cover the arch; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier is, the greater should be the curvature of the arch at its apex. When suspended arches are used, the intrados ought to be kept clear of the ground, that the arch may have its due effect.

When the ground is in such a state as to require the foundation merely to be rammed, the stones are hammer-dressed, so as to be as little taper as possible, then laid of a breadth proportioned to the weight that is to be rested upon them, and afterwards well rammed together. In general, the lower bed of stones may be allowed to project about a foot from the face of the wall on each side, and on this bed another course may be laid to bring the bed of stones on a level with the top of the trench. The breadth of this upper bed of stones should be four inches less than the lower one; that is, projecting about eight inches on either side of the wall. In all kinds of walling, each joint of every course must fall as nearly as possible in the centre, between two joints of the course immediately below it; for in all the various methods of laying stones or bricks, the principal aim is to procure the greatest lap on each other.

MORTAR.

In making mortar, particular attention must be paid to the quality of the sand, and if it contain any propor-

tion of clay or mud, or is brought from the sea-shore and contains saline particles, it must be washed in a stream of clear water till it be divested of its impurities. The necessity of the first has been clearly proved by Mr Smeaton, who, in the course of a long and meritorious attention to his profession of an engineer, has found, that when mortar, though otherwise of the best quality, is mixed with a small proportion of unburnt clay, it never acquires that hardness which without it, it would have attained; and, with respect to the second, it is evident, that so long as the sand contains saline particles it cannot become hard and dry. The sharper and coarser the sand is the better for the mortar, and the less the quantity of lime to be used; and sand being the cheapest of the ingredients which compose the mortar, it is more profitable to the maker. The exact proportions of lime and sand are still undetermined; but in general no more lime is required than is just sufficient to surround the particles of the sand, or sufficient to preserve the necessary degree of plasticity.

Mortar in which sand forms the greater portion, requires less water in its preparation, and consequently is sooner set. It is also harder and less liable to shrink in drying, because the lime, while drying, has a greater tendency to shrink than sand, which retains its original magnitude. The general proportions given by the London builders is $1\frac{1}{2}$ cwt. or 37 bushels of lime to $2\frac{1}{2}$ loads of sand; but if proper measures be taken to procure the best burnt lime and the best sand, and in tempering the materials, a greater portion of sand may be used. There is scarcely any mortar that has the lime well calcined, and the composition well beaten, but that will be found to require two parts of sand to one part of unslacked lime; and it is worthy of observation, that the more the mortar is beaten the less proportion of lime suffices.

Many experiments have been made with a view to obtain the most useful proportion of the ingredients, and among the rest Dr Higgins has given the following:—

Lime newly slacked one part,
Fine sand three parts, and
Coarse sand four parts.

He also found that one-fourth of the lime of bone-ashes greatly improved the mortar, by giving it tenacity, and rendering it less liable to crack in the drying.

It is best to slack the lime in small quantities as required

for use, about a bushel at a time, in order to secure to the mortar such of its qualities as would evaporate were it allowed to remain slacked for a length of time. But if the mortar be slacked for any considerable time previous to being used, it should be kept covered up, and when wanted be re-beaten. If care be taken to secure it from the action of the atmosphere, it may thus remain covered up for a considerable period without its strength being in the least affected; and indeed, some advantages are gained, for it sets sooner, is less liable to crack in the drying, and is harder when dry.

Grout, which is a cement containing a larger proportion of water than the common mortar, is used to run into the narrow interstices and irregular courses of rubble-stone walls; and as it is required to concrete in the course of a day, it is composed of mortar that has been a long time made and thoroughly beaten.

Mortar composed of pure lime, sand, and water, may be employed in the linings of reservoirs and aqueducts, provided a sufficient time is allowed for it to dry before the water is let in; but if a sufficient time is not allowed, and the water is admitted while the mortar is wet, it will soon fall to pieces. There are, however, certain ingredients which may be put into the common mortar to make it set immediately under the water; or, if the quick-lime composing the mortar contain in itself a certain portion of burnt clay, it will possess this property. For further information on this head the reader is referred to the sub-head—*Plastering*.

BRICKS.

The earth best adapted for the manufacture of brick is of a clayey loom, neither containing too much argillaceous matter, which causes it to shrink in the drying, nor too much sand, which has a tendency to render the ware both heavy and brittle. It should be dug two or three years before it is wrought, that it may, by an exposure to the action of the atmosphere, lose the extraneous matter of which it is possessed when first drawn from its bed; or, at least, should be allowed to remain one winter, that the frost may mellow and pulverize it sufficiently to facilitate the operation of tempering. As the quality of the brick is greatly dependent upon the tempering of the clay, great care should be taken to have this part of the process well done. Formerly the manner of performing it consisted in throwing the clay into

shallow pits, and subjecting it to the tread of men and oxen; but this method has of late been superseded by the clay or pug mill, which is a very eligible, though simple machine.

The clay or pug mill consists of a large vertical cone, having strong knives with a spiral arrangement and inclination fixed on its internal surface. Passing through the centre, and terminating in a pivot at the bottom, is a strong perpendicular shaft with similar radiating knives, so that the knives by the revolution of the shaft, cut, separate, and purify the clay, till it be reduced to a homogeneous paste, which passes through an orifice at the bottom into a receiver placed for that purpose. The clay is taken from the receiver to the moulder's bench, and is, either by a lad or a woman, cut into pieces somewhat larger than the mould, and passed on to the moulder, who works it into a mould, previously dipped in sand, and strikes off the superfluous parts with a flat smooth piece of wood. In this country, the mould used is about ten inches in length, and five inches in breadth, and the bricks when burnt are about nine inches long, four and a half inches broad, and two and a half inches thick. The degree of shrinking, however, is various, according to the temper and purity of the clay, and the degree of heat attained in the burning. A handy moulder is calculated to mould from about 5000 to 7000 per day. From the moulder's bench the bricks are carried to the hack, and arranged somewhat diagonally, one above the other, and two edgewise across, with a passage between the heads of each for the admission of air, till they be eight bricks in height. They are then left to dry. The time they take ere they require shifting depends entirely upon the weather, which when fine will be but a few days: they are then turned and re-set wider apart, and in six or eight days are ready for the clamp or kiln.

Clamps are generally used in the vicinity of London. They are made of the bricks to be burnt, and are commonly of an oblong form. The foundation is made either with the driest of the bricks just made, or with the commonest kind of brick, called place bricks. The bricks to be burnt are arranged tier upon tier as high as the clamp is intended to be, and a stratum of breeze or cinders to the depth of two or three inches is strewed between each layer of bricks, and the whole is finally covered with a thick stratum of breeze. At the west end of the clamp a perpendicular fire-place of about three feet in height is constructed, and flues are formed

by arching the bricks over so as to leave a space of about a brick in width. The flues run straight through the clamp, and are filled with a mixture of coals, wood, and breeze, which is pressed closely together. If the bricks are required to be burnt off quickly, which can be accomplished in the space of from twenty to thirty days according to the state of the weather, the flues must not exceed six feet distance apart; but if there is no urgent demand, the flues need not be nearer than nine feet, and the clamp may be allowed to burn slowly.

Coke has been recommended as a more suitable fuel for bricks than either coal or wood, as the dimensions of the flues and the stratum of the fuel are not required to be so great, which, since the measurement of the clamp has been restricted to certain limits by the interference of the legislature, is a point of some consideration; besides, the heat arising from the coke is more uniform, and more intense than what is produced by the other materials, so that the burning of the bricks is more likely to be perfect throughout. The saving which is thus produced may be calculated at about 32 per cent.

Kilns are also in common use, and are in many respects preferable to the clamp, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. A kiln will burn about 20,000 bricks at a time. The walls of a kiln are about a brick and a half thick, and incline inwards towards the top, so that the area of the upper part is not more than 114 square feet. The bricks are set on flat arches, with holes left between them, resembling lattice-work; and, when the kiln is completed, they are covered with pieces of broken brick and tiles, and some wood is kindled and put in to dry them gradually. When sufficiently dried, which is known by the smoke changing from a dark to a light transparent colour, the mouths of the kiln are stopped with pieces of brick, called *shinlog*, piled one upon another, and closed over with wet brick-earth. The shinlogs are carried so high as just to leave room for one faggot to be thrust into the kiln at a time, and when the brush-wood, furze, heath, faggots, &c. are put in, the fire is kindled, and the burning of the kiln commences. The fire is kept up till the arches assume a while appearance, and the flames appear through the top of the kiln; upon which the fire is allowed to slacken, and the kiln to cool by degrees. This process of alternately heating and slacking the kiln is continued till the bricks are thoroughly burnt, which, in

general, is in the space of forty-eight hours. The practice of steeping bricks in water after they have been burned, and then burning them again, has the effect of considerably improving the quality.

Bricks are of several kinds, the most usual of which are marls, stocks, and place bricks; but there is little difference in the mode of manufacturing them, except that great care is taken in preparing and tempering the marls.

The finest marls, called firsts, are selected for the arches of door-ways, &c. and are rubbed to their proper form and dimensions: and the next best, called seconds, for the principal fronts. The colour, a light yellow, added to the smooth texture, and superior durability of the marls, give them the precedence of the other descriptions of brick.

Grey stocks are somewhat like the seconds, but of inferior quality.

Place bricks, sometimes called pickings, sandal, or samel bricks, are such as from being the outermost in the clamp or kiln, have not been thoroughly burned, and are, in consequence, soft, of uneven texture, and of a red colour.

There are also burrs or clinkers, arising from the bricks being too violently burned, and sometimes several bricks are found run together in the kiln. They derive their colour from the nature of the soil of which they are composed, which, in general, is very pure. The best kinds are used as cutting bricks, and are called red rubbers. In old buildings they are very frequently to be seen ground to a fine smooth surface, and set in putty instead of mortar, as ornaments over arches, windows, door-ways, &c.; but though there are many beautiful specimens of red brick-work, yet these bricks cannot be judiciously used for the front walls of buildings. This objection arises from the colour being too heavy, and from its conveying to the mind, in the summer months, an unpleasant idea of heat; to which may be added, that as the fronts of the buildings have a greater or less proportion of stone and painted wood-work, the contrast in the colours is altogether injudicious. The colour of grey stocks, on the contrary, assimilates so much with the stones and paint, that they have obtained, in and near London, universal preference.

At the village of Hedgerley, near Windsor, red bricks are made which will stand the greatest heat: they are called Windsor bricks.

Bricks used for paving, are generally about an inch and a half in breadth; and, beside these, there are paving tiles,

which are made of a stronger clay, and are of a red colour. The largest are about twelve inches square, and one inch and a half thick: the next, though called ten-inch tiles, are about nine inches square, and one inch and a quarter thick.

About the year 1795, a patent was obtained by Mr Cartwright, for an improved system of making bricks, of which the following extract will furnish the reader with all necessary information.

"Imagine a common brick, with a groove or rebate on each side down the middle, rather more than half the width of the side of the brick; a shoulder will thus be left on either side of the groove, each of which will be nearly equal to one quarter of the width of the side of the brick, or to one-half of the groove or rebate. A course of these bricks being laid shoulder to shoulder, they will form an indented line of nearly equal divisions, the grooves or rebates being somewhat wider than the adjoining shoulders, to allow for the mortar or cement. When the course is laid on, the shoulders of the bricks, which compose it, will fall into grooves of the first course, and the shoulders of the first course will fit into the grooves or rebates of the second, and so with every succeeding course. Buildings constructed with this kind of brick, will require no bond timbers, as an universal bond runs through the whole building, and holds all the parts together; the walls of which will neither crack nor bilge without breaking through themselves. When bricks of this construction are used for arches, the sides of the grooves should form the radii of the circle, of which the intended arch is a segment; yet if the circle be very large, the difference of the width at the top and bottom will be so very trifling, as to render a minute attention to this scarcely if at all necessary. In arch-work, the bricks may either be laid in mortar, or dry, and the interstices afterwards filled up by pouring in lime, putty, plaster of Paris, &c. Arches upon this principle, having any lateral pressure, can neither expand at the foot, nor spring at the crown, consequently they want no abutments, requiring only perpendicular walls to be let into, or to rest upon; neither will they want any superincumbent weight on the crown to prevent their springing up. The centres also may be struck immediately, so that the same centre, which never need be many feet wide, may be regularly shifted as the work proceeds. But the most striking advantage attending this invention is, the security it affords against the ravages of fire; for, from the peculiar properties of this kind of arch, requiring no abutments, it may be laid upon, or let into common walls, no stronger than what is required for timbers so as to admit of brick floorings."

Having said thus much on the laying of the foundation, the mixing of the mortar, and the manufacture of the brick, we shall next proceed to treat on the principles of the art of masonry, as practised in the present day.

MASONRY,

Is the art of cutting stones, and building them into a mass, so as to form the regular surfaces which are required in the construction of an edifice.

The chief business of the mason is to prepare the stones, make the mortar, raise the wall with the necessary breaks, projections, arches, apertures, &c. and to construct the vaults, &c. as indicated by the design.

A wall built of unhewn stone, whether it be built with mortar or otherwise, is called a *rubble wall*. Rubble work is of two kinds, coursed and uncoursed. In coursed rubble the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of equal thickness; and the masonry, which may be of different thicknesses, is laid in horizontal courses. In uncoursed rubble the stones are placed promiscuously in the wall, without any attention being paid to the placing them in courses: and the only preparation the stones undergo, is that of knocking off the sharp angles with the thick end of a tool called a *scabling* hammer. Walls are generally built with an ashlar facing of fine stone, averaging about four or five inches in thickness, and backed with rubble work or brick.

Walls backed with brick or uncoursed rubble, are liable to become convex on the outside, from the great number of joints, and the difficulty of placing the mortar, which shrinks in proportion to the quantity, in equal portions, in each joint; consequently, walls of this description are much inferior to those where the facing and backing are built of the same material, and with equal care, even though both of the sides be uncoursed. When the outside of a wall is faced with ashlar, and the inside is coursed rubble, the courses of the backing should be as high as possible and set within beds of mortar. Coursed rubble and brick backings are favourable for the insertion of bond timber; but in good masonry, wooden bonds should never be in continued lengths, as in case of either fire or rot the wood will perish, and the masonry will, by being reduced, be liable to bend at the place where the bond was inserted.

When timber is to be inserted into walls for the purposes of fastening buttons for plastering, or skirting, &c. the pieces of timber ought to be so disposed that the ends of the pieces be in a line with the wall.

In a wall faced with ashlar, the stones are generally about 2 feet or 2½ feet in length, 12 inches in height, and 8 inches in thickness. It is a very good plan to incline the back of each stone, to make all the backs thus inclined run in the same direction, which gives a small degree of lap in the setting of the next course; whereas, if the backs are parallel

to the front, there can be no lap where the stones run of an equal depth in the thickness of the wall. It is also advantageous to the stability of the wall to select the stones, so that a thicker and a thinner one may succeed each other alternately. In each course of ashlar facing, either with rubble masonry, or brick backing, thorough-stones should occasionally be introduced, and their number be in proportion to the length of the course. In every succeeding course, the thorough-stones should be placed in the middle of every two thorough-stones in the course below; and this disposition of bonds should be punctually attended to in all cases where the courses are of any great length. Some masons, in order to prove that they have introduced sufficient bonds into their work, choose thorough-stones of a greater length than the thickness of the wall, and afterwards cut off the ends; but this is far from an eligible plan, as the wall is not only subject to be shaken, but the stone is itself apt to split. In every pier, between windows and other apertures, every alternate jamb-stone ought to go through the wall with its bed perfectly level. When the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them, upon the lintel crowning them, and upon the stones at the ends of the courses of the pier which are adjacent to the architrave-jamb, every alternate stone ought to be a thorough-stone: and if the piers between the apertures be very narrow, no other bond stone is required; but where the piers are wide, the number of bond-stones are proportioned to the space. Bond-stones must be particularly attended to in all long courses below and above windows.

All vertical joints, after receding about an inch with a close joint, should widen gradually to the back, thereby forming hollow spaces of a wedge-like figure, for the reception of mortar, rubble, &c. The adjoining stones should have their beds and vertical joints filled, from the face to about three-quarters of an inch inwards, with oil and putty, and the rest of the beds must be filled with well tempered mortar. Putty cement will stand longer than most stones, and will even remain permanent when the stone itself is mutilated. All walls cemented with oil-putty, at first look unsightly; but this disagreeable effect ceases in a year or less, when, if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly be perceptible.

In selecting ashlar, the mason should take care that each stone invariably lays on its natural bed; as from careless-

ness in this particular, the stones frequently flush at the joints, and sooner admit the corrosive power of the atmosphere to take effect.

It ought also to be observed, that; in building walls, or insulated pillars of small horizontal dimensions, every stone should have its bed perfectly level, and be without any concavity in the middle; because, if the beds are concave, the joints will most probably flush when the pillars begin to sustain the weight of the building. Care should also be taken, that every course of masonry in such piers be of one stone.

Having thus given to the practical mason an outline of the subject of walling, we will proceed to the consideration of the more difficult branches of the art, that of constructing arches and vaults.

DEFINITIONS.

An *arch*, in masonry, is that part of a building which is suspended over a given plane, supported only at its extremities, and concave towards the plane.

The upper surface of an arch is called the *extrados;* and the under surface, or that which is opposite the plan, the *intrados.*

The supports of an arch are called the *spring walls.*

The *springing lines*, are those common to the supports and the intrados; or the line which forms the intersection of the arch with the surface of the wall which supports it.

The *chord*, or *span*, is a line extending from one springing line to the opposite one.

Section of the hollow of the arch, is a vertical plane, supposed to be contained by the span and the intrados.

The *height*, or *rise* of the arch, is a line drawn at right angles from the middle of the chord, or spanning line, to the intrados.

The *crown* of the arch is that part which the extremity of the perpendicular touches.

The *haunches*, or *flanks*, of the arch, are those parts of the curve between the crown and the springing line.

When the base of the section, or spanning line, is parallel to the horizon, the section will consist of two equal and similar parts, so that when one is applied to the other, they will be found to coincide.

Arches are variously named according to the figure of the section of a solid that would fill the void, as *circular*, *elliptical*,

cycloidal, *catenarian*, *parabolical*, &c. There are also *pointed composite*, and *lancet*, or *Gothic arches*.

A *rampant arch* is when the springing lines are of two unequal heights.

When the intrados and extrados of an arch are parallel, it is said to be *extradossed*.

There are, however, other terms much used by masons; for example, the semicircular are called *perfect arches*, and those less than a semicircle, *imperfect*, *surbused*, or *diminished* arches.

Arches are also called *surmounted*, when they are higher than a semicircle.

A *vault* is an arch used in the interior of a building, overtopping an area of a given boundary, as a passage, or an apartment, and supported by one or more walls, or pillars, placed without the boundary of that area.

Hence an arch in a wall is seldom or never called a vault; and every vault may be called an arch, but every arch cannot be termed a vault.

A *groin vault* is a complex vault, formed by the intersection of two solids, whose surfaces coincide with the intrados of the arches, and are not confined to the same heights. An arch is said to stand upon splayed jambs, when the springing lines are not at right angles to the face of the wall.

In the art of constructing arches and vaults, it is necessary to build them in a mould, until the whole is closed: the mould used for this purpose is called a *centre*. The intrados of a simple vault is generally formed of a portion of a cylinder, cylindroid, sphere, or spheroid, that is, never greater than the half of the solid: and the springing lines which terminate the walls, or when the vault begins to rise, are generally straight lines, parallel to the axis of the cylinder, or cylindroid.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of a sphere less than an hemisphere.

Every vault which has an horizontal straight axis, is called a *straight vault*; and in addition to what we have already said, the concavities which two solids form at an angle, receive likewise the name of arch.

An arch, when a cylinder pierces another of a greater diameter, is called *cylindro-cylindric*. The term cylindro is applied to the cylinder of the greatest diameter, and the term cylindric to the less.

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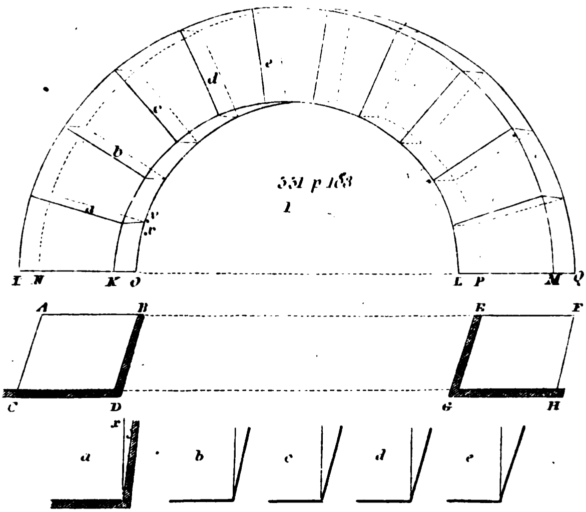

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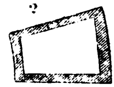

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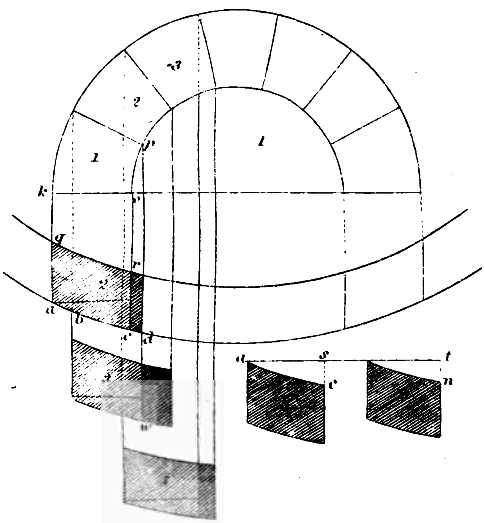

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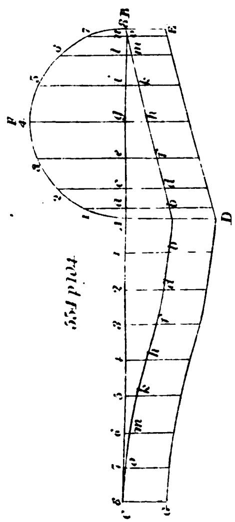

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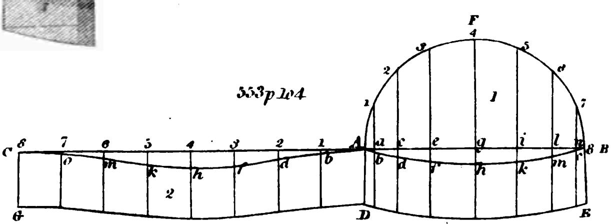

If a cylinder intersect a sphere of greater diameter than the cylinder, the arch is called a *sphero-cylindric arch;* but on the other hand, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is called a *cylindro-spheric* arch.

If a cylinder pierce a cone, so as to make a complete perforation through the cone, two complete arches will be formed, called *cono-cylindric arches;* but, on the contrary, if a cone pierce a cylinder, so that the concavity made by the cone is a conic surface, the arch is called a *cylindro-conic* arch.

If, in a straight wall, there be a cylindric aperture continuing quite through it, two arches will be formed, called *plano-cylindric arches.*

Every description of arch is, in a similar manner to the above, denoted by the two preceding words; the former ending in *o*, signifying the principal vault, or surface cut through; and the latter in *ic*, signifying the description of the aperture which pierces or intersects the wall or vault.

When groins are introduced merely for use, they may be built either of brick or stone; but, when introduced by way of proportion or decoration, their beauty will depend on the generating figures of the sides, the regularity of the surface, and the acuteness of the angles, which should not be obtunded. In the best buildings, when durability and elegance are equally required, they may be constructed of wrought stone; and, when elegance is wanted, at a trifling expense, of plaster, supported by timber ribs.

In stone-cutting, a narrow surface formed by a point or chisel, on the surface of a stone, so as to coincide with a straight edge, is called a *draught.*

The formation of stone arches has always been considered a most useful and important acquisition to the operative mason; in order, therefore, to remove any difficulties which might arise in the construction of arches of different descriptions, both in straight and circular walls, we shall here introduce a few examples, which, it is hoped, with careful examination, will greatly facilitate a knowledge of some of the most abstruse parts of the art.

Fig. 551, No. I. To find the moulds necessary for the construction of a semicircular arch, cutting a straight wall obliquely.

Let ABCDEFGH be the plan of the arch; IKLM the outer line; and NOPQ the inner line on the elevation.

a b c d e, on the elevation, shows the bevel of each joint or bed from the face of the wall; and *a b c d e* below, gives the mould for the same, where *x y* on the elevation corresponds with *x y* at *a*.

The arch mould, fig. 551, No. 2, is applied on the face of the stone, and on being applied to the parts of the plan, gives, of course, the bevel of each concave side of the stone with the face, that is K to O, on the elevation.

Fig. 552. To find the mould for constructing a semicircular arch in a circular wall.

No. 1 is the elevation of the arch; and No. 2 the plan of the bottom bed from *q* to *r*.

a to *b* is what the arch gains on the circle from the bottom bed *k o* to *l*; and *c* to *d* is the projection of the intrados to *p*, on the joint *l*, *p*.

Nos. 2, 3, 4, are plans of the three arch-stones, 1, 2, 3, in the elevation; and Nos. 5 and 6 are moulds to be applied to the beds of stones 1 and 2, in which *s c* equals *s c* in No. 2, and *t w* equals *t w* in No. 3.

In No. 1, *k l p o* is the arch or face mould.

When the reader is thoroughly proficient in the construction of arches, under given datas, as the circumstances of the case may point out, he may proceed to investigate the principles of spherical domes and groins.

Figs. 553 and 554 show the principles of developing the soffits of the arches in the two preceding examples. In each the letters of reference are alike, and the operation is precisely the same.

Let ABDE be the plan of the opening in the wall; and AFB the elevation of the arch: produce the chord AB to C, divide the semicircle AFB into any number of parts, the more the better, and with the compasses set to any one of these divisions, run it as many times along A C as the semicircle is divided into; then draw lines, perpendicular to BC, through every division in the semicircle and the line C A, and set the distance 1 *b*, 2 *d*, 3 *f*, &c. respectively equal to *a b*, *c d*, *e f*, &c. and then by tracing a curve through these points, and finding the points in the line GD, in the same manner, the soffit of the arch is complete.

Fig. 555, shows the method of constructing spherical domes.

No. 1 mould is applied on the spherical surface to the vertical joints; and No. 2 mould on the same surface to the other joints; and in both cases, the mould tends to the centre of the dome.

3, 4, 5, 6, 7, and 8, are moulds which apply on the convex surface to the horizontal joint, the lines *a b*, *c d*, *e f*, &c. being at right angles to the different radii, *b c*, *d c*, *f c*, &c. and produced until they intersect the perpendicular *a c*; the different intersections are the centres which give the circular leg of the mould, and the straight part gives the horizontal joint.

Fig. 556 exhibits the plan of a groined vault.

Lay down the arch, either at the full or half size, on a floor or piece of floor-cloth, then divide and draw on the plan the number of joints in the semicircular arch, and from the intersections with the diagonals, draw the transverse joints on the plan, and produce them till they touch the intradoes of the elliptical arch, the curve of which may be found by setting the corresponding distances from the line of the base to the curve; thus *a b* equal to *a b*. This being accomplished, draw the joints of the ellipti-

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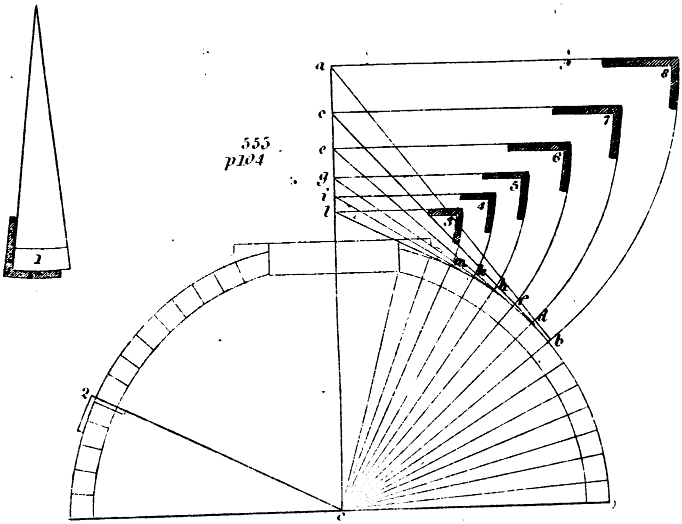

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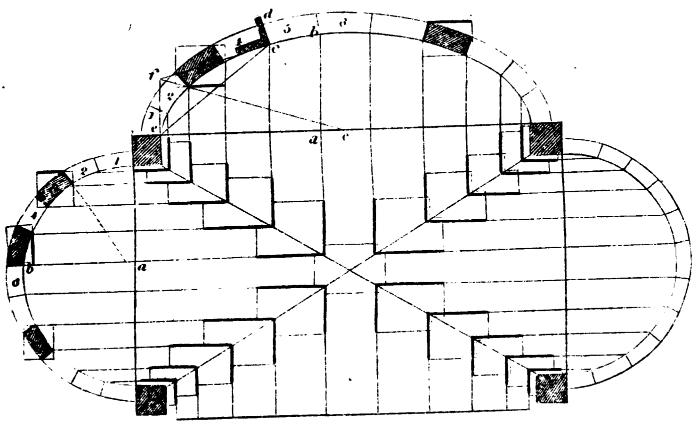

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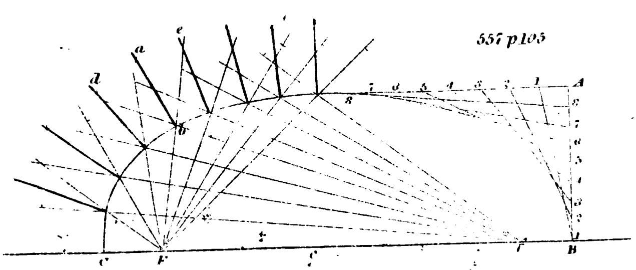


cal arch in the manner of which we give *c d*, as a specimen. To draw the joint *c d*, draw the chord *e c* and bisect it, draw a line from the centre *c*, through the bisecting point, and produce it till it touches the perpendicular *e f*; and *c d*, being at right angles to *e f*, will be the joint required. In the same manner the others are found.

By examination, it will be seen, that a rectangle circumscribing the mould 3, 3, gives the size of the stone in its square state, and, that if each stone in both arches be thus enclosed, the dimensions for each will be found, as also the position in which the moulds must be placed. The dark lines give the different bevels which must be carefully prepared and applied to the stones in the manner represented in the figure.

Fig. 557. To draw the joints of the stones for an elliptical arch in a wall, &c.

The curve is here described by the intersection of lines, which, certainly, gives the most easy and pleasing curve, as segments of circles apply only under certain data, or in the proportion which the axis major has to the axis minor, while the intersection of lines apply to any description of ellipsis. Find the foci F. In an ellipsis the distance of either focus from one extremity of the axis minor is equal to the semi-axis major; that is, D F is equal to *c* C. Then to find any joint, *a b*, draw lines from both foci through the point *b*, as F *e*, *f d*, and bisect the angle *d b e* by the line *a b*, which is the joint required.

Having thus given a general outline of the principles of masonry, and accompanied the same with a few examples on the most abstruse parts of the art, we shall conclude this part of our treatise with the methods employed in the mensuration of masons' work.

Rough stone or marble is measured by the foot cube: but in measuring for workmanship, the superficies or surface, for plain work, is measured before it is sunk. In measuring ashlar, one bed and one upright joint are taken and considered plain work. In taking the plain sunk, or circular work, and the straight moulded, or circular moulded work, particular care is required to distinguish the different kinds of work in the progress of preparing the stone. In measuring strings, the weathering is denominated *sunk work*, and the grooving *throatings*.

Stone cills to windows, &c. are, in general, about 4¾ inches thick and 8 inches broad, and are weathered at the top, which reduces the front edge to about 4 inches, and the horizontal surface at the top to about 1½ inch on the inside; so that the part taken away is 6½ inches broad and three-quarters of an inch deep. Cills, when placed in the wall, generally project about 2½ inches. The horizontal part left on the inside of the cill is denominated *plain work*; and the sloping part *sunk work*; and in the dimension book are entered thus,—

$1\frac{1}{2}$
4
$2\frac{1}{2}$
—
8 inches the breadth of the plain work in the cill, according to the above dimensions—then,

	4			
	8	2 8	Plain work.
	4			
	$6\frac{1}{2}$	2 2	Sunk work.
2	8			
	4	6	Plain to ends.
	4 0		of throating.

No account is taken of the sawing.

Cornices are measured by girthing round the moulded parts, that is, the whole of the vertical and under parts, called moulded work:—for example, suppose a cornice project one foot, girth two feet, and is 40 feet in length, then the dimensions will be entered as under,—

40		
2	80	Moulded work.
40		
1	40	Sunk work at top.

All the vertical joints must be added to the above.

Cylindrical work is measured in the girth; and the surface is calculated to be equivalent to plain work twice taken.

For example, suppose it be required to measure the plain work or a cylinder, 10 feet long, and 5 feet in circumference, the dimensions would then be entered.

10 0	
5 0	500 Sup[l]. plain work, double measure.

Paving-slabs and chimney-pieces are found by superficial measure, as also are stones under two inches thick.

The manner in which the dimensions of a house are taken, vary according to the place and the nature of the agreement.

In Scotland, and most parts of England, if the builder engages only for workmanship, the dimensions are taken round the outside of the house for the length, and the height is taken for the width, and the two multiplied

together, gives the superficial contents. This, however, applies only when the wall is of the same thickness all the way up; and when not, as many separate heights are taken as there are thicknesses. This mode of measuring gives something more than the truth, by the addition of the four quoins, which are pillars of two feet square; but this is not more than considered sufficient to compensate the workman for the extra labour in plumbing the quoins.

If there be a plinth, string, course-cornice, or blocking course, the height is taken from the bottom of the plinth to the top of the blocking course, including the thickness of the same; that is, the measurer takes a line or tape and begins, we will suppose, at the plinth, then stretching the line to the top, bends it into the offset, or weathering, and, keeping the corner tight at the internal angle, stretches the line vertically upon the face of the wall, from the internal angle to the internal angle of the string; then girths round the string to the internal angle at the top of the string, and keeping the line tight at the upper internal angle, stretches it to meet the cornice; he then bends it round all the mouldings to the internal angle of the blocking course, from which he stretches the string up to the blocking course, to the farther extremity of the breadth of the top of the same; so that the extent of the line is the same as the vertical section stretched out: this dimension is accounted the height of the building.

With respect to the length, when there are any pilasters, breaks, or recesses, the girth of the whole is taken at the length. This method is, perhaps, the most absurd of any admitted in the art of measuring; since this addition in height and length, is not sufficient to compensate for the value of the workmanship on the ornamental parts.

The value of a rood of workmanship must be first obtained by estimation, that is, by finding the cost of each kind of work, such as plinth, strings, cornices, and architraves, &c. and adding to them the plain ashlar work, and the value of the materials, the amount of which, divided by the number of roods contained in the whole, give the mean price of a single rood. When the apertures or openings in a building are small, it is not customary to make deductions either for the materials or workmanship which are there deficient, as the trouble of plumbing and returning the quoins, is considered equivalent to the deficiency of materials occasioned by such aperture.

Elsam's Gentleman's and Builder's Assistant, gives the following information on the practice of measuring rough stone-work.

To find the number of perches contained in a piece of rough stone-work.

If the wall be at the standard thickness, that is, 12 inches high, 18 inches thick, and 21 feet long, divide the area by 21, and the quotient, if any, will be the answer in perches, and the remainder, if any, is feet. If the wall be more or less than 18 inches thick, multiply the area of the wall by the number of inches in thickness, which product, divided by 18, and that quotient by 21, will give the perches contained.

Example. A piece of stone-work is 40 feet long, 20 feet high, and 24 inches thick, how many perches are contained in it?

```
         40 length.
         20 height.
        ----
        800
         24
        ----
       3200
       1600
      ------ 21)        P.  F. In.
18)   19200  (1066 ( 50  16  8
      18      105
      ---     ---
      120      16
      108     ---
      ---
       120
       108
       ---
        12 equal to 8 inches.
```

The method last described, of finding the value of mason's work, is usually adopted, the perch being the standard of the country; but the most expeditious way of ascertaining the value, is to cube the contents of the wall, and to charge the work at per foot. To ascertain the value of common stone-work, a calculation should be made of the prime cost of all the component parts, consisting of the stones in the quarry, the expense of quarrying, land carriage to the place where it is to be used, with the extra trouble and consequent expense in carrying the stone one, two, three, or more stories higher. Also the price of the lime when delivered, together with the extra expense of wages to workmen, if in the country; all these circumstances must be taken into consideration in finding the value of a perch of common stone-work, the expense of which will be found to vary according to

local circumstances, in degrees scarcely credible; wherefore a definite price cannot, with propriety, be fixed.

BRICKLAYING.

In building upon an inclined plane, or rising ground, the foundation must be made to rise in a series of level steps, according to the general line of the ground, to insure a firm bed for the courses, and prevent them from sliding; for if this mode be not adopted, the moisture in the foundation in wet weather will induce the inclined parts to descend, to the manifest danger of fracturing the walls and destroying the building.

In walling, in dry weather, when the work is required to be firm, the best mortar must be used; and the bricks must be wetted or dipped in water, as they are laid, to cause them to adhere to the mortar, which they would not do if laid dry; for the dry sandy nature of the brick absorbs the moisture of the mortar and prevents adhesion.

In carrying up the wall, not more than four or five feet of any part should be built at a time; for, as all walls shrink immediately after building, the part which is first carried up will settle before the adjacent part is carried up to it, and, consequently, the shrinking of the latter will cause the two parts to separate; therefore, no part of a wall should be carried higher than one scaffold, without having its contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, to receive the bond of the adjoining parts on the right and left.

There are two descriptions of bonds; *English bond*, and *Flemish bond*. In the *English bond*, a row of bricks is laid lengthwise on the length of the wall, and is crossed by another row, which has its length in the breadth of the wall, and so on alternately. Those courses in which the lengths of the bricks are disposed through the length of the wall, are termed *stretching courses*, and the bricks *stretchers*: and those courses in which the bricks run in the thickness of the lengths of the walls, *heading courses*, and the bricks *headers*.

The other description of bond, called *Flemish bond*, consists in placing a header and a stretcher alternately in the same course. The latter is deemed the neatest, and most elegant; but in the execution is attended with great incon-

venience, and, in most cases, does not unite the parts of a wall with the same degree of firmness as the English bond. In general, it may be observed, that, whatever advantages are gained by the English bond in tying a wall together in its thickness, they are lost in the longitudinal bond; and *vice versâ*. To remove this inconvenience, in thick walls, some builders place the bricks in the cone at an angle of forty-five degrees, parallel to each other, throughout the length of every course, but reversed in the alternate courses; so that the bricks cross each other at right angles. But even here, though the bricks in the cone have sufficient bond, the sides are very imperfectly tied, on account of the triangular interstices formed by the oblique direction of the internal bricks against the flat edges of those in the outside.

Concerning the English bond, it may be observed, that, as the longitudinal extent of a brick is nine inches, and its breadth four and a half, to prevent two vertical joints from running over each other at the end of the first stretcher from the corner, it is usual, after placing the return corner stretcher, which occupies half of the length of this stretcher, and becomes a header in the face, as the stretcher is below, to place a quarter brick on the side, so that the two together extend six inches and three-quarters, being a lap of two inches and a half for the next header. The bat thus introduced is called a *closer*. A similar effect may be obtained by introducing a three-quarter bat at the corner of the stretching course, so that the corner header being laid over it, a lap of two inches and a quarter will be left at the end of the stretchers below for the next header, which being laid on the joint below, the stretchers, will coincide with its middle.

In the winter, it is very essential to keep the unfinished wall from the alternate effects of rain and frost; for if it is exposed, the rain will penetrate into the bricks and mortar, and, by being converted into ice, expand, and burst or crumble the materials in which it is contained.

The decay of buildings, so commonly attributed to the effects of time, is, in fact, attributable to this source; but as finished edifices have only a vertical surface, the action and conter-action of the rain and frost extend not so rapidly as in an unfinished wall, where the horizontal surface permits the rain and frost to have easy access into the body of the work. Great care, therefore, must be taken, as soon as the frost or stormy weather sets in, to cover the un-

finished walls, either with straw, which is the most common, or weather boarding.

When weather boarding is employed, it is advisable to have a good layer of straw between the work and the boarding, and to place the boarding in the form of stone-coping, to throw the water off equally on both sides.

A number of very pleasing cornices and other ornaments may be formed in brick-work, by the mere disposition of the bricks, without cutting; and if cut, a simple champher will be sufficient. A great defect, however, is very often observable in these ornaments, particularly in the bulging of arches over windows; which arises from mere carelessness, in rubbing the bricks too much on the inside; whereas, if due care were taken to rub them exact to the gauge, their geometrical bearings being united, they would all tend to one centre, and produce a well-proportioned and pleasing effect.

In steining wells, it is necessary first to make a centre, consisting of a boarding of inch or inch and a half stuff, ledged within with three circular rings, upon which the bricks, all headers, are laid. The vacuity between the bricks towards the boarding, are to be filled in with tile or other pieces of brick. As the well-sinker proceeds to excavate the ground, the centre with its load of bricks sinks, and another similarly charged is laid upon it, and another upon that, and so on till the wall is complete, the centring remaining with the brick-work. This plan is generally adopted in London, at least where the soil is sandy and loose; where it is firm, centrings are not requisite. In the country, among many other methods, the following is most approved:—rings of timber, without the exterior boarding, are used; upon the first ring, four or five feet of bricks are laid, then a second ring, and so on. But the mode before described is by far the most preferable; as in the latter the sides of the brick-work are apt to bulge in sinking, particularly if great care be not taken in filling and ramming the sides uniformly, so as to keep the pressure regular and equal. In steining wells and building cess-pools, a rod of brick-work will require at least 4760 bricks.

As the construction of walls, arches, groins, &c. in brick-work, approximates so nearly to that of stone-work, and as the same observations generally apply, further information would, perhaps, be considered superfluous; we shall, therefore, conclude this article with some practical observations on the measuring of brick-work.

Brick-work is measured and valued by the rod. The contents of a rod of brick-work is $16\frac{1}{2}$ feet square; consequently, the superficial rod contains 272.25, or $272\frac{1}{4}$ square feet; but as the quarter has been found troublesome in calculation, 272 superficial feet has been admitted as the standard.

The standard thickness of a brick wall is $1\frac{1}{2}$ brick laid lengthwise; therefore, if 272 square feet be multiplied by 13 inches, the result will be 306 cubic feet, or a rod.

A rod of standard brick-work, making the necessary allowance for mortar and waste, will require 4500 bricks; but this quantity is of course ruled by the size of the brick, and the closeness of the joints.

A foot of reduced brick-work requires 17 bricks; a foot superficial of marl facing, laid in Flemish bond, 8 bricks; and a foot superficial of gauged arches, 10 bricks. In paving, a yard will require 82 paving bricks, or 48 stock bricks, or 38 bricks laid flat.

A square of tiling contains 100 superficial feet; and requires of plain tiles, 800 at a six-inch gauge, 700 at a seven-inch gauge, or 600 at an eight-inch gauge.

The distance between the respective laths must depend on the pitch of the roof; and one roof may require a 6, 7, and 8 inch gauge. For instance, a kirt roof will require, in the kirt part, a $7\frac{1}{2}$ or 8 inch gauge, and in the upper part, 6, $6\frac{1}{2}$, or 7 inch gauge, decreasing in the ratio of the angle of elevation.

A square of plain tiling will require a bundle of laths, more or less, according to the pitch; with two bushels of lime, one bushel of sand, and a peck of tile-pins.

Laths are sold by the thousand, or bundle; and each bundle is supposed to contain 100 laths, though the exact number depends on the length; the 3 feet containing 5 score, the 4 feet 4 score, the 5 feet 3 score, and so on in proportion.

A square of pan-tiling requires 180 tiles, laid at a ten-inch gauge; and one bundle, containing 12 laths, ten feet long.

In lime measure, 25 struck bushels, or 100 pecks, make a hundred of lime; 8 gallons, a bushel dry measure; and 268 cubic inches, one gallon.

In measuring sand, 24 heaped, or 30 struck bushels make one load; and 24 cubic feet weighs one ton.

A load of mortar, which ought to contain half a hundred of lime, with a proportionate quantity of sand, is 27 cubic feet.

Excavations of the earth are measured by the number of cubic yards which they contain, therefore, to find the number of cubic yards in a trench, find the solidity of the trench in cubic feet, and divide it by 27, the number of cubic feet in a yard, and the quotient, is the number of cubic yards, and the remainder the number of cubic feet.

For example, the length of a trench is 60 feet, the depth 3 feet, and the breadth 2 feet.

```
      60
       3
     ---
     180
       2
     --- yds. ft.
 27)360 (13  9 the answer.
     27
     ---
      90
      81
     ---
       9
     ---
```

In the horizontal dimensions, if the trench be wider at the top than it is at the bottom, and equal at the ends, take half the sum of the two dimensions for a mean breadth; and if the breadth of one end of the trench exceed that of the other, so as to have two mean breadths, differing from each other, take half the sum of the two added together, as a mean breadth of the whole.

In measuring the footing of a wall, multiply the length and the height of the courses together; then multiply the product by the number of half bricks in the mean breadth, divide the last product by 3, and the quotient is the answer in reduced feet. Instead of measuring the height of the footing, it is customary to allow three inches to each course in height, or multiply the number of courses by 3, which gives the height in inches.

To find the contents in rods of a piece of brick work.

Case I. If the wall be of the standard thickness, divide the area of the wall by 272, and the quotient is the number of rods, and the remainder the number of feet; but if the wall be either more or less than a brick and a half in thickness, multiply the area of the wall by the number of half bricks, that is, the number of half lengths of a brick; divide the product by 3, which will reduce the wall to the standard thickness of 1½ brick, then divide the quotient by 272, and it will give the number of rods.

Case II. Divide the number of cubic feet contained in the wall by 306; the quotient will give the number of rods, and the remainder the number of cubic feet.

Case III. Multiply the number of cubic feet in a wall by 8; divide the pro-

duct by 9; and the quotient will give the area of the wall at the standard: divide this standard area by 272, and the quotient will give the number of rods; the remainder the reduced feet.

Example. The length of a wall is 60 feet, the height 20 feet, and the thickness equal to the length of three bricks; it is therefore required to know how many rods of brick-work is contained in the said wall?

```
By Case I.          63
                    20
                  ----
                  1200
                     6
                  ----
                3)7200
                  ----
            272)2400(8 rods 224 feet the answer.
                2176
                ----
                 224
                ----

Case II.            60
                    20
                  ----
                  1200
                    2.3 thickness of wall.
                  ----
                  2400
                   300
                  ----
              306)2700(8 rods 252 feet the answer.
                  2448
                  ----
                   252
                  ----

Case III.           60
                    20
                  ----
                  1200
                    2.3
                  ----
                  2400
                   300
                  ----
                  2700
                     8
                 -----
               9)21600
                 -----
            272)2400(8 rods 224 feet, as in Case I.
                2176
                ----
                 224
                ----
```

In the calculation of brick-work, where there are several walls of different thicknesses, it will be quite unnecessary to use the divisors 3 and 272, as will be hereafter shown.

In taking dimensions for workmanship, it is usual to allow the length of each wall on the external side, to compensate for plumbing the angles; but this practice must not be resorted to for labour and materials, as it gives too much quantity in the height of the building or story by two pillars of brick; and in the horizontal dimensions by the thickness of the walls.

In measuring walls, faced with bricks of a superior quality, most surveyors measure the whole as common work, and allow an additional price per rod for the facing, as the superior excellence of the work, and quality of the bricks may deserve.

Every recess or aperture made in any of the faces must be deducted; but an allowance per foot lineal should be made upon every right angle, whether external or internal, excepting when two external angles may be formed by a brick in breadth, and then only one of them must be allowed.

Gauged arches are sometimes deducted and charged separate; but as the extra price must be allowed in the former case, it will amount to the same thing.

In measuring walls containing chimneys, it is not customary to deduct the flues; but this practice, so far as regards the materials, is unjust, though, perhaps, by taking the labour and materials together, the overcharge, with respect to the quantity of bricks and mortar, may, in some degree, compensate for the loss of time: on the other hand, if the proprieter finds the materials, it is not customary to allow for the trouble of forming the flues, which, consequently, is a loss to the contractor who has engaged by task-work or measure.

If the breast of a chimney project from the face of the wall, and is parallel to it, the best method is, to take the horizontal and vertical dimensions of the face, multiply them together, and multiply the product by the thickness, taken in the thinnest part, without noticing the breast of the chimney; then find the solidity of the breast itself, add these solidities together, and the sum will give the solidity of the wall, including the vacuities, which must be deducted for the real solidity. Nothing more is necessary to be said of the shaft, than to take its dimensions in height, breadth, and thickness, in order to ascertain its solidity.

If a chimney be placed at an angle, with the face of the breast intersecting the two sides of the wall, the breast of the chimney must be considered a triangular prism. To take the dimensions:—from the intersections of the front of the breast into the two adjacent walls, draw two lines on the floor, parallel to each adjacent wall; then the triangle on the floor, included between the front and these lines, will be equal to the triangle on which the chimney stands, and, consequently, equal to the area of the base. To attain the area of the triangular base, the dimensions may be taken in three various ways, almost equally easy; one of which is, to take the extent of the base, which is the horizontal dimension of the breast, and multiply it by half of the perpendicular; or multiply the whole perpendicular by half the base: but as this calculation would, in cases of odd numbers, run somewhat long, a more preferable method is, to multiply the whole base by the whole perpendicular, and take half of the product, which will give the area on which the chimney stands; and which, multiplied by the height, gives the solid contents of the chimney. From this contents is to be deducted the vacuity for the fire-place.

A row of plain tiles, laid edge to edge, with their broad surfaces parallel to the termination of a wall, so as to project over the wall at right angles to the vertical surface, is called *single plain tile creasing*; and two rows, laid one above the other, the one row breaking the joints of the other, are called *double plain tile creasing*.

Over the plain tile creasing a row of bricks is placed on edge, with their length in the thickness of the wall, and are called a *barge course*, or *cope*.

The bricks in gables, which terminate with plain tile creasing coped with bricks, in order to form the sloping bed for the plain tile creasing, must be cut, and the sloping of the bricks thus, is called *cut splay*.

Plain tile creasing and cut splay are charged by the foot run; and the latter is sometimes charged by the superficial foot.

A brick wall built in pannels between timber quarters is called *brick nogging;* and is generally measured by the yard square, the quarters and nogging pieces being included in the measure.

Pointing is the filling up the joints of the bricks after the walls are built. It consists in raking out some of the mortar from the joints, and filling them again with blue mortar, and in one kind of pointing, the courses are simply

marked with the end of a trowel, called *flat-joint pointing;* but if, in addition to flat-joint pointing, plaster be inserted in the joint with a regular projection, and neatly paved to a parallel breadth, it is termed *hick-pointing*, or *hick-joint pointing*, or formerly, *hick, and patt.* Pointing is measured by the foot superficial, including in the price, mortar, labour, and scaffolding.

Rubbed and gauged work is set in putty or mortar; and is measured either by the foot superficial, or the foot run, according to the manner in which it is constructed.

In measuring canted bow windows, the sides are considered as continued straight lines; but the angles on the exterior side of the building, whether they be external or internal, are allowed for in addition, and paid for under the denomination of *run of bird's mouth.* All angles within the building, if oblique, from whatever cause they are made, either by straight or circular bows, or the splays of windows, are allowed for, under the head of *run cut splay.*

Brick cornices are measured by the lencal foot; but as various kinds of cornices require more or less difficulty in the execution, the price must depend on the labour and the value of the materials used.

Garden walls are measured the same as other walls, but if interrupted by piers, the thin part may be measured as in common walling, and the piers by themselves, making an allowance, at per foot run, for the right angles. The coping is measured by itself, according to the kind employed.

Paving is laid either with bricks or tiles, and is measured by the yard square. The price, per yard, is regulated by the manner in which the bricks or tiles are laid, whether flat or edge-ways, or whether any of them be laid in sand or mortar.

The circular parts of drains may be reduced either to the standard, or the cubic foot; and the number of rods may, if required, be taken. The mean dimensions of the arch may be found, by taking the half sum of the exterior and interior circumferences; but, perhaps, it were better to make the price of the common measure, whether it be a foot, a yard, or rod, greater as the diameter is less; but as the reciprocal ratio would increase the price too much in small diameters, perhaps prices at certain diameters would be a sufficient regulation.

The following tables will be found an acquisition to those persons to whom a saving of time is an object:—

TABLE I.

This Table shows what quantity of bricks are necessary to construct a piece of brick-work of any given dimensions, from half a brick to two bricks and a half in thickness; and by which the number for any thickness may be found.

This Table is at the rate of 4500 bricks to the rod of reduced brick-work, including waste.

Area of the face of wall.	The number of bricks thick and the quantity required.				
	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
1	5	11	16	22	27
2	11	22	33	44	55
3	16	33	49	66	82
4	22	44	66	88	110
5	27	55	82	110	137
6	33	66	99	132	165
7	38	77	115	154	193
8	44	88	132	176	220
9	49	99	148	198	288
10	55	110	165	220	275
20	110	220	330	441	551
30	165	330	496	661	827
40	220	441	661	882	1102
50	275	551	827	1102	1378
60	330	661	992	1323	1655
70	386	772	1158	1544	1930
80	441	882	1323	1764	2205
90	496	992	1488	1985	2480
100	551	1102	1654	2205	2757
200	1102	2205	3308	4411	5514
300	1654	3308	4963	6617	8272
400	2205	4411	6617	8823	11,029
500	2757	5514	8272	11,029	13,786
600	3308	6617	9926	13,235	16,544
700	3860	7720	11,580	15,441	19,301
800	4411	8823	13,235	17,647	22,058
900	4963	9926	14,889	19,852	24,816
1000	5514	11,029	16,544	22,058	27,573
2000	11,029	22,058	33,088	44,117	55,147
3000	16,544	33,088	49,632	66,176	82,720
4000	22,058	44,117	66,176	88,235	110,294
5000	27,573	55,147	82,720	110,294	137,867
6000	33,088	66,176	99,264	132,352	165,441
7000	38,602	77,205	115,808	154,411	193,014
8000	44,117	88,235	132,352	176,470	220,588
9000	49,632	99,264	148,896	198,529	248,161
10,000	55,147	110,294	165,441	220,588	275,735
20,000	110,294	220,588	330,882	441,176	551,470
30,000	165,441	330,882	496,323	661,764	827,205
40,000	220,588	441,176	661,764	882,352	1.102,940
50,000	275,735	551,470	827,205	1,102,940	1,378,675
60,000	330,882	661,764	992,646	1,323,528	1,654,410
70,000	386,029	772,058	1,158,087	1,544,116	1,930,145
80,000	441,176	882,352	1,323,528	1,764,704	2,205,880
90,000	496,323	992,646	1,488,969	1,985,292	2,481,615

The left-hand column contains the number of superficial feet contained in the wall to be built: the adjacent columns show the number of bricks required to build a wall of the different thicknesses of ½, 1, 1½, 2, and 2½ bricks.

Example. Suppose it be required to find the number of bricks necessary to build a wall 1 brick thick, containing an area of 5760 feet? First look for 5000 in the left-hand column, and you will find that it takes 55,147 bricks, add to this quantity, the number necessary for each of the other component parts, and we shall have the following:—

5000	will require	55,147
700	. . . .	7,720
60	. . . .	661
5760		63,528

TABLE II.

Shows the number of rods contained in any number of superficial feet, from 1 to 10,000, and from ½ a brick to 2½ bricks; and thence by addition, to any number, and to any thickness, at the rate of 4500 bricks to the rod.

Feet sup.	½ brick.				1 brick.				1½ brick.				2 bricks.				2½ bricks.			
	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.
1	0	0	0	4	0	0	0	8	0	0	1	0	0	0	1	4	0	0	1	8
2	0	0	0	8	0	0	1	4	0	0	2	0	0	0	2	8	0	0	3	4
3	0	0	1	0	0	0	2	0	0	0	3	0	0	0	4	0	0	0	5	0
4	0	0	1	4	0	0	2	8	0	0	4	0	0	0	5	4	0	0	6	8
5	0	0	1	8	0	0	3	4	0	0	5	0	0	0	6	8	0	0	8	4
6	0	0	2	0	0	0	4	0	0	0	6	0	0	0	8	0	0	0	10	0
7	0	0	2	4	0	0	4	8	0	0	7	0	0	0	9	4	0	0	11	8
8	0	0	2	8	0	0	5	4	0	0	8	0	0	0	10	8	0	0	13	4
9	0	0	3	0	0	0	6	0	0	0	9	0	0	0	12	0	0	0	15	0
10	0	0	3	4	0	0	6	8	0	0	10	0	0	0	13	4	0	0	16	8
11	0	0	3	8	0	0	7	4	0	0	11	0	0	0	14	8	0	0	18	4
12	0	0	4	0	0	0	8	0	0	0	12	0	0	0	16	0	0	0	20	0
13	0	0	4	4	0	0	8	8	0	0	13	0	0	0	17	4	0	0	21	8
14	0	0	4	8	0	0	9	4	0	0	14	0	0	0	18	8	0	0	23	4
15	0	0	5	0	0	0	10	0	0	0	15	0	0	0	20	0	0	0	25	0
16	0	0	5	4	0	0	10	8	0	0	16	0	0	0	21	4	0	0	26	8
17	0	0	5	8	0	0	11	4	0	0	17	0	0	0	22	8	0	0	28	4
18	0	0	6	0	0	0	12	0	0	0	18	0	0	0	24	0	0	0	30	0
19	0	0	6	4	0	0	12	8	0	0	19	0	0	0	25	4	0	0	31	8
20	0	0	6	8	0	0	13	4	0	0	20	0	0	0	26	8	0	0	33	4
21	0	0	7	0	0	0	14	0	0	0	21	0	0	0	28	0	0	0	35	0
22	0	0	7	4	0	0	14	8	0	0	22	0	0	0	29	4	0	0	36	8
23	0	0	7	8	0	0	15	4	0	0	23	0	0	0	30	8	0	0	38	4
24	0	0	8	0	0	0	16	0	0	0	24	0	0	0	32	0	0	0	40	0
25	0	0	8	4	0	0	16	8	0	0	25	0	0	0	33	4	0	0	41	8
26	0	0	8	8	0	0	17	4	0	0	26	0	0	0	34	8	0	0	43	4
27	0	0	9	0	0	0	18	0	0	0	27	0	0	0	36	0	0	0	45	0
28	0	0	9	4	0	0	18	8	0	0	28	0	0	0	37	4	0	0	46	8
29	0	0	9	8	0	0	19	4	0	0	29	0	0	0	38	8	0	0	48	4
30	0	0	10	0	0	0	20	0	0	0	30	0	0	0	40	0	0	0	50	0
31	0	0	10	4	0	0	20	8	0	0	31	0	0	0	41	4	0	0	51	8

Feet sup.	½ brick.				1 brick.				1½ brick.				2 bricks.				2½ bricks.			
	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.	R.	Q.	F.	In.
32	0	0	10	8	0	0	21	4	0	0	32	0	0	0	42	8	0	0	53	4
33	0	0	11	0	0	0	22	0	0	0	33	0	0	0	44	0	0	0	55	0
34	0	0	11	4	0	0	22	8	0	0	34	0	0	0	45	4	0	0	56	8
35	0	0	11	8	0	0	23	4	0	0	35	0	0	0	46	8	0	0	58	4
36	0	0	12	0	0	0	24	0	0	0	36	0	0	0	48	0	0	0	60	0
37	0	0	12	4	0	0	24	8	0	0	37	0	0	0	49	4	0	0	61	8
38	0	0	12	8	0	0	25	4	0	0	38	0	0	0	50	8	0	0	63	4
39	0	0	13	0	0	0	26	0	0	0	39	0	0	0	52	0	0	0	65	0
40	0	0	13	4	0	0	26	8	0	0	40	0	0	0	53	4	0	0	66	8
41	0	0	13	8	0	0	27	4	0	0	41	0	0	0	54	8	0	1	0	4
42	0	0	14	0	0	0	28	0	0	0	42	0	0	0	56	0	0	1	2	0
43	0	0	14	4	0	0	28	8	0	0	43	0	0	0	57	4	0	1	3	8
44	0	0	14	8	0	0	29	4	0	0	44	0	0	0	58	8	0	1	5	4
45	0	0	15	0	0	0	30	0	0	0	45	0	0	0	60	0	0	1	7	0
46	0	0	15	4	0	0	30	8	0	0	46	0	0	0	61	4	0	1	8	8
47	0	0	15	8	0	0	31	4	0	0	47	0	0	0	62	8	0	1	10	4
48	0	0	16	0	0	0	32	0	0	0	48	0	0	0	64	0	0	1	12	0
49	0	0	16	4	0	0	32	8	0	0	49	0	0	0	65	4	0	1	13	8
50	0	0	16	8	0	0	33	4	0	0	50	0	0	0	66	8	0	1	15	4
60	0	0	20	0	0	0	40	0	0	0	60	0	0	1	12	0	0	1	32	0
70	0	0	23	4	0	0	46	8	0	1	2	0	0	1	25	4	0	1	48	8
80	0	0	26	8	0	0	53	4	0	1	12	0	0	1	38	8	0	1	65	4
90	0	0	30	0	0	0	60	0	0	1	22	0	0	1	52	0	0	2	14	0
100	0	0	33	4	0	0	66	8	0	1	32	0	0	1	65	4	0	2	30	8
200	0	0	66	8	0	1	65	4	0	2	64	0	0	3	62	8	1	0	61	4
300	0	1	32	0	0	2	64	0	1	0	28	0	1	1	60	0	1	3	24	0
400	0	1	65	4	0	3	62	8	1	1	60	0	1	3	57	4	2	1	54	8
500	0	2	30	8	1	0	61	4	1	3	24	0	2	1	54	8	3	0	17	4
600	0	2	64	0	1	1	60	0	2	0	56	0	2	3	52	0	3	2	48	0
700	0	3	29	4	1	2	58	8	2	2	20	0	3	1	49	4	4	1	10	8
800	0	3	62	8	1	3	57	4	2	3	52	0	3	3	46	8	4	3	41	4
900	1	0	28	0	2	0	56	0	3	1	16	0	4	1	44	0	5	2	4	0
1000	1	0	61	4	2	1	54	8	3	2	48	0	4	3	41	4	6	0	34	8
2000	2	1	54	8	4	3	41	4	7	1	28	0	9	3	14	8	12	1	1	4
3000	3	2	48	0	7	1	28	0	11	0	8	0	14	2	56	0	18	1	36	0
4000	4	3	41	4	9	3	14	8	14	2	56	0	19	2	29	4	24	2	2	8
5000	6	0	34	8	12	1	1	4	18	1	36	0	24	2	2	8	30	2	37	4
6000	7	1	28	0	14	2	56	0	22	0	16	0	29	1	44	0	36	3	4	0
7000	8	2	21	4	17	0	42	8	25	2	64	0	34	1	17	4	42	3	38	8
8000	9	3	14	8	19	2	29	4	29	1	44	0	39	0	58	8	49	0	5	4
9000	11	0	8	0	22	0	16	0	33	0	24	0	44	0	32	0	55	0	40	0
10,000	12	1	1	4	24	2	2	8	36	3	4	0	49	0	5	4	61	1	6	8

The left hand column contains the area of the wall in superficial feet: the adjacent columns the quantity, reduced to the standard thickness, according to the different thicknesses on the top.

Example. What is the quantity of reduced brick-work in a wall containing 4540 superficial feet, 2 bricks thick?

Divide the number as in the preceding table, into its component parts, say 4540 = 4000 + 500 + 40, then by the table.

	R.	Q.	F.	In.
4000 contains	19	2	29	4
500 . . .	2	1	54	8
40 . . .	0	0	53	4
	22	1	1	4

The same by rule.

```
                4540
                   4 number of half bricks.
                ----
           3) 18160 (       R.  Q.  F.  In. as above.
                ----
         272) 6053 + 4 (22   1   1   4
              544
              ---
               613
               544
               ---
¼ of a rod 68)  69 (1
                68
                --
                 1
```

TABLE III.

Shows the value of reduced brick-work per rod, calculated at the several prices of £3 5*s*. £3 10*s*. £3 15*s*. £4 0*s*. £4 5*s*. and £4 10*s*. per rod for mortar, labour, and scaffolding; and of bricks from £1 10*s*. to £3 0*s*. per thousand; allowing 4500 bricks to the rod.

Bricks per thousand.			Mortar and Labour 3*l*. 5*s*. per rod.			Mortar and Labour 3*l*. 10*s*. per rod.			Mortar and Labour 3*l*. 15*s*. per rod.			Mortar and Labour 4*l*. 0*s*. per rod.			Mortar and Labour 4*l*. 5*s*. per rod.			Mortar and Labour 4*l*. 10*s*. per rod.		
£.	*s*.	*d*.	£.	*s*.	*d*.	£.	*s*.	*d*.	£.	*s*.	*d*.	£.	*s*.	*d*.	£.	*s*.	*d*.	£.	*s*.	*d*.
1	10	0	10	0	0	10	5	0	10	10	0	10	15	0	11	0	0	11	5	0
1	12	0	10	9	0	10	14	0	10	19	0	11	4	0	11	9	0	11	14	0
1	14	0	10	18	0	11	3	0	11	8	0	11	13	0	11	18	0	12	3	0
1	16	0	11	7	0	11	12	0	11	17	0	12	2	0	12	7	0	12	12	0
1	18	0	11	16	0	12	1	0	12	6	0	12	11	0	12	16	0	13	1	0
2	0	0	12	5	0	12	10	0	12	15	0	13	0	0	13	5	0	13	10	0
2	2	0	12	14	0	12	19	0	13	4	0	13	9	0	13	14	0	13	19	0
2	4	0	13	3	0	13	8	0	13	13	0	13	18	0	14	3	0	14	8	0
2	6	0	13	12	0	13	17	0	14	2	0	14	7	0	14	12	0	14	17	0
2	8	0	14	1	0	14	6	0	14	11	0	14	16	0	15	1	0	15	6	0
2	10	0	14	10	0	14	15	0	15	0	0	15	5	0	15	10	0	15	15	0
2	12	0	14	19	0	15	4	0	15	9	0	15	14	0	15	19	0	16	4	0
2	14	0	15	8	0	15	13	0	15	18	0	16	3	0	16	8	0	16	13	0
2	16	0	15	17	0	16	2	0	16	7	0	16	12	0	16	17	0	17	2	0
2	18	0	16	6	0	16	11	0	16	16	0	17	1	0	17	6	0	17	11	0
3	0	0	16	15	0	17	0	0	17	5	0	17	10	0	17	15	0	18	0	0

Example. What is the price of a rod of brick-work, when the rate of bricks is £2 2*s*. per thousand, and the price of mortar £4 5*s*. per rod?

Look from the given column of bricks until you come under £4 5*s*. the given price of labour and mortar, and you will find £13 14*s*. the price of the rod.

CARPENTRY.

This branch of building comprises the art of employing timber in the construction of edifices.

The art of employing timber in building may be classed under two distinct branches, Carpentry and Joinery.

Carpentry comprehends the large and rough description of work, or that which is requisite in the construction and stability of an edifice; and *Joinery*, the fittings up and decorative work, so necessary to the completion of a building.

Carpentry is, in general, valued by the cubical foot; and joinery by the superficial foot.

The principal operations which timbers have to undergo, from the time of their arrival in the carpenter's yard to their final destination in an edifice, may be classed under two general heads; those which respect individual prices, and those which respect their dependence on others.

Under the former of these heads is the pit-saw, by means of which whole pieces of timber are divided, and reduced into their respective sized scantlings.

The term *scantling* implies dimensions in breadth and thickness, without any regard to length.

Planing is the operation by which wood is reduced to a smooth and uniform surface, by means of an instrument called a plane, which takes a thin shaving off the surface of the wood, as it is moved backwards and forwards in a straight line by the hands of the workmen. There are, however, other operations of the plane besides that of reducing timber to an uniform and smooth surface, termed *grooving*, *rebating*, and *moulding*.

Grooving is forming a channel on the surface of a piece of wood, by taking away so much of the solid as is of the shape and size of the groove required.

Rabating, or *rebating*, is reducing a piece by taking away from the angles a prism of the shape and size of the rabate required, so as to form an internal angle, and generally a right angle. This operation is frequently required in constructing door cases, and the frames of casement windows: the rabate, or groove, being intended as a ledge for the door or casement to rest in.

The pieces being cut into their proper scantlings, the next operation is the joining them together.

In this department we shall treat, first, of the most approved methods of lengthening beams, by what is termed scarfing or joining them in pieces; secondly, of the strengthening of beams by trussing; thirdly, of the methods of joining two timbers at angles, in any given direction; and lastly, of the mode of connecting several timbers in order to complete the design, and to effect certain powers respectively required by each individual piece.

To lengthen a piece of timber implies the act of joining or fastening two distinct pieces, so that a part of the end of one shall lap upon the end of another, and the surfaces of both, being one continued plane, form a close joint, called by workmen a *scarf*. It is manifest, that two bodies, joined together and intended to act as one continued piece, in a state of tension, or compression, cannot, by any possible means, be so strong as either pieces taken separately. It, therefore, requires much attention, and careful discrimination, in the choice and selection of such methods as are the most applicable to the peculiar circumstances of the case. Every two pieces of timber joined in the manner thus described, and, indeed, in most other cases, require some force to compress them equally on each side, and more particularly when the pieces are light; for this purpose iron bolts are used, which act as a tie, and possess the same effect as two equal and opposite forces would have in compressing the beam on each side the joint: and as the cohesive power of iron is very great, the hole, which is made to receive the bolt, may be of such dimensions as will not, in the least degree, tend to diminish the strength of the timber. When wooden pins are used, the bore is larger, and the joints weaker; consequently the two pieces, thus connected, are not held together by any compression of the pin, but merely by the friction of the individual pieces.

No specific distance can be laid down for the length of the scarf, though, in general, it may be observed, that a long scarf has but little effect in diminishing the cohesive strength of a compound piece of timber; on the contrary, it affords an opportunity of increasing the number of bolts.

Fig. 558 shows the method of joining two pieces of timber by means of a single step on each piece.

By this method more than one-half the power is lost; and this scarf is not calculated to resist the force of tension equal to a single piece sawed half through its thickness from the opposite side, at a distance equal to the length of the scarf;

by the application of straps, however, it may be made to resist a much greater force.

Fig. 559 represents a scarf with parallel joints, and a single table upon each piece.

In this the cohesive strength is decreased in a greater degree than the preceding example, by the projection of the table; but this affords an opportunity of driving a wedge through the joint between the ends of the tables, and thereby forcing the abutting parts to a joint.

A scarf of this description to be longer than those which have no tables, and the tranverse parts of the scarf, must be strapped and bolted.

Fig. 560 presents us with the same opportunity of wedging as before.

In this figure, if the parts L M and N O be compressed together by bolts as firmly as if they were but one piece, and if the projection of the tables be equal to the transverse parts of the joints L and O, the loss of strength, compared with that of a solid piece, will be no more than what it would be at L and O.

Strapping across the tranverse part of the joint is much the best and most effectual way of preventing the pieces from being drawn from each other, by the sliding of the longitudinal parts of the scarf, and, therefore, giving to the bolts an oblique position.

Fig. 561 is a scarf formed by several steps.

In this, if all the transverse parts of the steps be equal, and the longitudinal parts strongly compressed by bolts, the loss of strength will only be a fourth, compared to that of a solid piece, there being four transverse parts, that is, the part which the end of the steps is of the whole.

Fig. 562 is a scarf with a bevel joint, and equally as eligible for ordinary purposes as any in use.

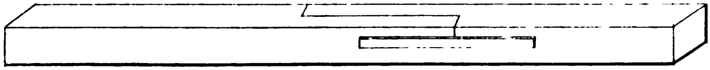
Figs. 561 and 563. Scarfs intended for longer bearings than the preceding one.

Fig. 564 represents the method of constructing a compound timber, when two pieces are not of adequate length to allow them to lap, by means of a third piece joined to both by a double scarf, formed by several gradations or steps, the pieces abutting upon each other with the middle of the connecting piece over their abutment.

That which shall next claim our attention is a consideration of the principles and the best methods of strengthening beams by trussing.

When girders are extended beyond a certain length, they bend under their own weight, and the degree of curvature increases in a proportion far greater than that of their lengths. The best method to obviate this *sagging*, as it is

558 p 123



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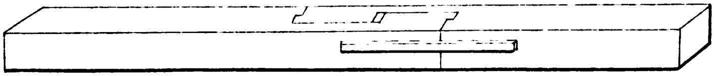

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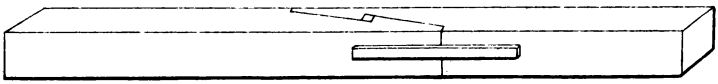

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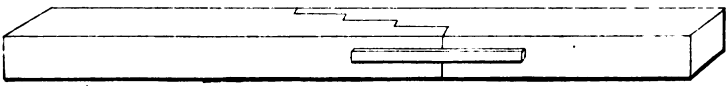

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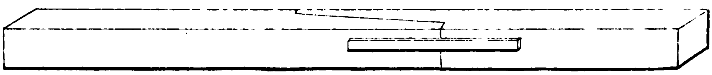

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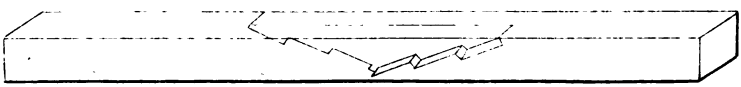

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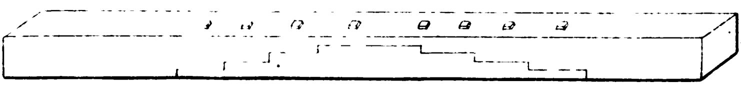

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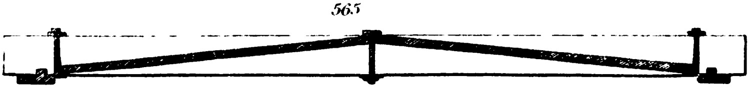
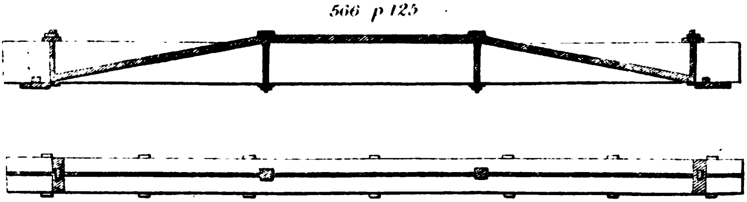


566 p 125



termed, without the support of posts, &c. is to make the beam in two equal lengths, and insert a truss, so that when the two pieces are confined together by bolts, the truss may be included between them, and cause them to act as a tie. To prevent any unfavourable results from natural tendency of the timbers to shrink, the posts of the truss may be made of iron, and screwed and nutted at the ends; and to give a still stronger abutment, the braces may be let in with grooves into the side of each flitch, or piece, which form the beam. The ends of the abutments are also made of iron, screwed, or nutted, at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle, that the braces may abut upon the whole dimension of their section; or, otherwise, the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted.

These methods may be constructed either with one king-bolt in the middle, or with a truss-bolt at one-third of the length from each end. When two bolts are applied, they include a straining place in the middle. The two braces may be constructed of oak, or cast or wrought iron; but the latter material is seldom used: for, as all metals are liable to contract, wood is considered the best material. With respect to the bolts, iron is indispensable.

The higher the girder is, the less are the parts liable to be effected by the stress; and, consequently, the risk of their giving way under heavy weights, or through long bearings, is less.

Figs. 565 and 566 are two examples of girders calculated from their rise to sustain very heavy weights. If the tie beam be very strong, the abutments may be wedged; but the wedges ought to be very long, and a little taper, that there may be no inclination to rise. The excess of length may afterwards be taken off.

In joining two timbers together, in any given direction, the joinings, as practised by carpenters, are almost infinitely various; and though some are executed with a view merely to gratify the eye, the majority have decided advantages, and each, in peculiar cases, is to be preferred. In this treatise, our limits will not permit us to enter upon a description of such as yield no substantial benefit, or are employed only in connecting small work; but, even in these, the skill of the workman may at all times be discovered by his selection of materials. It may here be observed, that, as all timber is either more or less, according to the dryness,

and the quality of the timber used, subject to shrink, the carpenter should very carefully consider how much the dimensions of his framings will be effected by it, and so arrange the inferior pieces that their shrinkage shall be in the same direction as the shrinkage of the framing, and so conduce to the greater stability of the whole. If this be not attended to, the parts will separate and split asunder.

Two pieces of timber may be connected either by making both planes of contact parallel with or at right angles to the fibres, or by making the joint parallel with the fibres of the one piece, and at right or oblique angles to the other, or at oblique angles to the fibres of both pieces.

If two pieces of timber are connected, so that the joint runs parallel with the fibres of both, it is called a *longitudinal joint;* but when the place of the joint is at right angles to the fibres of both, an *abutting joint.* Butting and mitre joints are seldom used in carpentry.

When two pieces of timber are joined together at one or more angles, the one piece will meet the other and form one angle, or by crossing it make two angles, or the two pieces will cross each other and form four angles.

In all the following cases of connecting two timbers, it is supposed, that the sides of the pieces are parallel with the fibres, or, when the fibres are crooked, as nearly so as possible; and that each piece, the four sides being at right angles to each other, has at least one of its surfaces in the same plane with those of the other. Thé angle or angles so formed will be either right or obtuse.

Fig. 567 is an example of a notched joint, which is the most common and simple form, and, in some cases, the strongest for joining two timbers at one or more angles, particularly when bolted at the joint. The form of the joint may be varied, according to the position of the sides of the pieces, the number of angles, the quantity and direction of the stress on the one or both pieces, or by any combination of their circumstances. Notching admits two pieces to be joined at from one to four angles; but joining by mortise and tenon admits only from one to two angles.

In joining by mortise and tenon, four sides of the mortise should, if possible, be at right angles to each other, and to the surface whence it is recessed, and two of these sides parallel with each of the sides which forms a right angle with the side from which the mortise is made: the fifth plane, that is, the bottom of the mortise, is parallel with the top or surface from which the mortise is made. Four sides of the tenon should be parallel to the four sides of the piece; but there are many cases where a digression is unavoidable.

In the application of timbers to buildings, we will here suppose, that all pieces cut for use have a rectangular section, and when laid down, have their sides perpendicular to, and parallel with, the horizon. If two pieces of timber, therefore, are to be joined at four angles, cut a notch in one piece equal to the breadth of the other, so as to leave the remaining part of the thickness sufficiently strong, and insert the other piece in the notch; or, if the work is required to be very firm, notch each piece reciprocally to each other's breadth, and fasten them together by pins, spikes, or bolts, as the case may require. This form is applicable when the pieces are equally exposed to a strain.

Fig. 568 will fully elucidate this description of joint.

The framing of timber by dove-tail notching is principally applicable to horizontal framing, where the lower timber is sufficiently supported. Where the lower timber is unsupported it is common to use mortise and tenon, which does not materially weaken the timber; but when the timber is notched from the upper side, the operation reduces its thickness, and consequently impairs its strength, though, if the solid of one piece fill the excavation of the other, and both be lightly driven or forced together, according to Du Hamel, it will, if not cut more than one-third through, rather increase than decrease in strength. It may, however, be observed, that in large works, where heavy timbers are employed, it is difficult, and almost impossible, to fit the mortise and tenon with due accuracy; and even if the joints were closely fitted at first, the shrinking would occasion cavities on the sides, that would render the tenons of no avail, because the axis of fracture would be nearer to the breaking or under-side of the supporting piece. What has been here said with respect to timbers placed horizontally, applies to framing in every position, when the force is to fall on the plane of the sides; and if a number of pieces thus liable to lateral pressure on either side, are to be framed into two other stiff pieces, the mortise and tenon will prove best for the purpose.

If it be required to connect two pieces of timber so as to form two right angles, and to be immovable, when the transverse is held or fixed fast, and the standing piece pulled in a direction of its length, cut a dove-tail notch across the breadth of the transverse piece, and notch out the vertical sides of the standing piece at the end, so as to form a similar and equal solid. In some kinds of work, besides the dove-tail, an additional notch is cut to receive the shoulder of

the lower piece. If the position of these pieces be horizontal, and the upper is of sufficient weight, or is pressed down by any considerable force, when the pieces are placed together, the dove-tail will be sufficiently strong without the assistance of pins, spikes, or bolts. This construction requires the timbers to be well seasoned; for otherwise the shrinking will permit the standing piece to be drawn out of the transverse, and thus defeat the purpose of the construction.

In introducing binding joists, which will, as they have to support the bridging joists and boarding of the floor, be framed into girders, there will be a considerable strain at the extremities, so that it is necessary, in order to make the tenons sufficiently strong, to have a shorter bearing tenon attached to the principal tenon, with a sloping shoulder above, called a *tusk*, which term is likewise applied to this tenon, called the *tusk tenon*.

When two parallel pieces, which are quite immovable, are to have another piece framed between them, the principle is, to insert the one end of the tenon of the piece to be framed in a shallow mortise, and make a long mortise in the opposite side of the other timber; so that when the cross piece is moved round the shoulder of the other extremity as a centre, it may slide home to its situation. This mode of framing a transverse piece between two others, is employed in trimming in ceiling joists, which joists are seldom or never cut and fitted into the binding joists before the building is covered over. The binding joists are always mortised before they are disposed in the situation to receive the ceiling joists.

When a transverse piece of timber is to be framed between two parallel joists, whose vertical surfaces are not parallel, turn the upper edge of the transverse piece downwards upon the upper horizontal surface of the joints, mark the interval, or distance between them, upon the surface of the transverse piece now under; then placing the edge over the place where it is intended to let down, turn the transverse piece in the way it is intended to be framed, apply a straight edge to the oblique surface of the joist, and slide the transverse piece so as to bring the mark on the upper side of it on a line with the straight edge, which being done, proceed in the same manner with the other end, and the two lines drawn on the vertical sides of the intermediate piece will give the shoulders of the tenons. This act of framing a transverse joist between two others is termed *tumbling in*

joists; and is particularly useful when the timber is warped or twisted.

In order that the reader may the more fully understand the preceding description of the joinings of timbers, we have annexed a plate, (to which the subjoined description refers,) of the best methods now in practice.

Fig. 467. No. 1 and 2, and 3 and 4, exhibit two methods of a simple joint, where the two pieces are halved upon each other; in both of which the end of one piece does not pass the outer surface of the other. No. 3 and 4 represent the two pieces before put together.

Fig. 568 is a method of joining timber, when the end of one piece passes the end of the other at a small distance. No. 1 represents the pieces before joined.

Fig. 569 shows how two pieces may be joined by what is termed a niche.—In this case, the two pieces should be fixed to another by a bolt at right-angles to the niche joint.

Fig. 570. How one piece of timber may be joined to another, when one of the pieces is extended on both sides of the other piece. Nos. 1 and 2 show the pieces before put together.

Fig. 571 shows the manner of joining the binding joists and girders. No. 1. The binding joist prepared for being joined to the girder.

Fig. 572 is the general and most approved method of framing the rafter foot into the girder.

Fig. 573 is a section of the beam, showing the different shoulders of the rafter foot.

Fig. 574 is another example, preferable to the former, because the abutment of the inner part is better supported. In this the beam, when no broader than the rafter is thick, may be weakened, in which case it would require a much deeper socket than is here given; an advantage would be gained by introducing a joint like fig. 575.

Fig. 576 is the method of introducing iron straps to confine the foot of the rafter to the tie-beam.

When it is found necessary to employ iron straps for strengthening a joint, considerable attention is required to place them properly. The first thing to be ascertained is the direction of the strain. We must then endeavour, as near as we can, to resolve this strain into a strain parallel to each piece, and another perpendicular to it. Then the strap which is to be made fast to any of the pieces, must be so fixed that it shall resist in the direction parallel to the piece.

The strap which is generally misplaced, is that which connects the foot of the rafter with the tie-beam. It binds down the rafter; but does not act against its horizontal thrust. It should be placed farther back on the beam, and have a bolt through it, to allow it to turn round; and should embrace the rafter almost horizontally near the foot, and be notched square with the back of the rafter. The example given in No. 10 combines these requisites. By

moving round the eye-bolt, it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. Straps which have eye-bolts on the very angles, and allow motion round them, are considered the most perfect.

Fig. 577 exhibits two methods of connecting the struts of a roof, or partition, &c. with the king-post.

If the action of a piece of timber on another does not extend, but compress, the same, there is no difficulty whatever in the joint, indeed joining is unnecessary : it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that no lateral pressure, which may cause one of the pieces to slide on the butting joint, be produced. At the joggle of a king-post, a very slight mortise and tenon, with a rafter, or straining beam, is sufficient. It is generally best to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. For instance, the joint *a* is preferable to *b*, and, indeed, to any uneven joints, which never fail to produce very unequal pressures, by which some of the parts are crippled, and others splintered off.

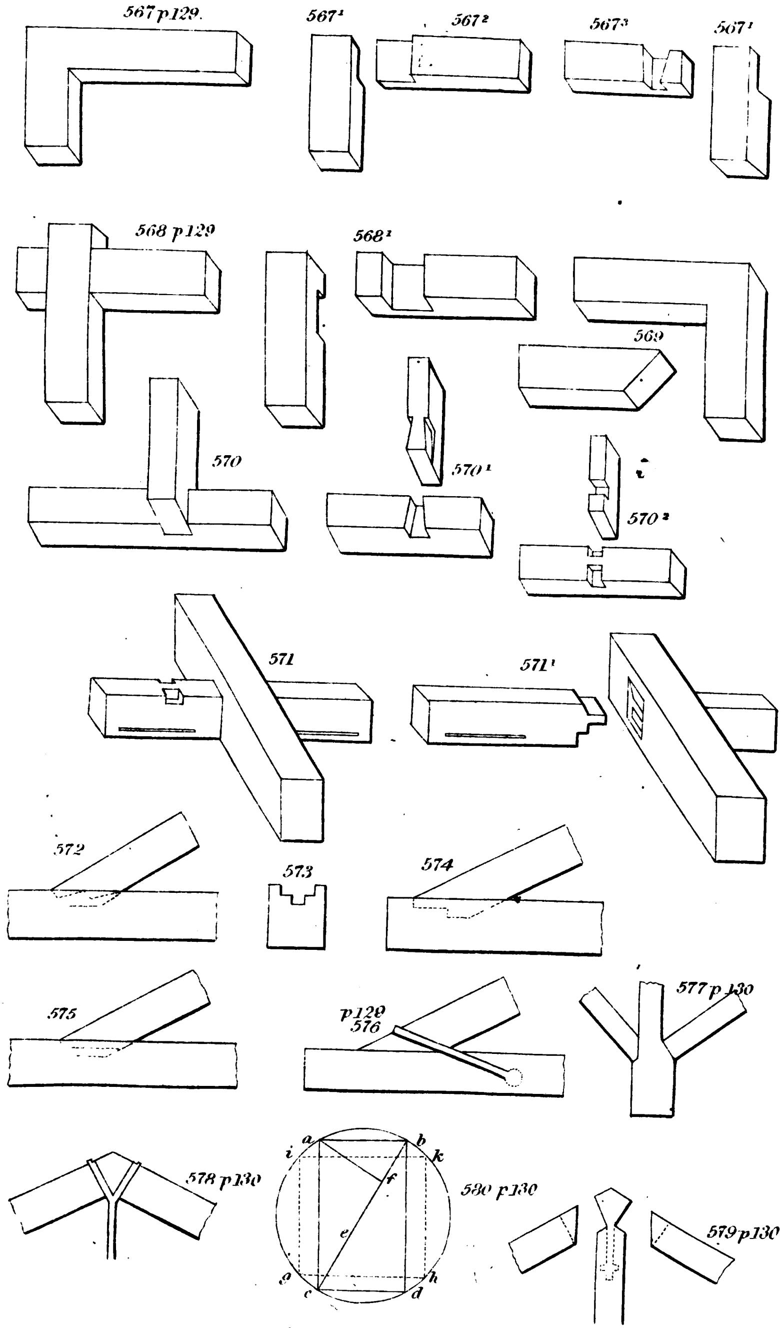
Fig. 578 is the method of securing the tie-beam and principles, when the king-post is made of an iron rod.

Fig. 579 shows a method of joining the principals with the king-post by means of an iron dove-tail, which is received in a mortise at the head of each principal.

Trusting that the reader will be able, from the above description, to comprehend the best method of joining timbers, we shall next proceed to describe the modes of connecting several timbers, in order to complete the design, and to effect certain powers respectively required by each individual piece.

In framing centres for groins, the boarding which forms the interior surface is supported by transverse ribs of timber, which are either constructed simply, or with trusses, according to the magnitude of the work; and, as a groin consists generally of two vaults intersecting each other, one of them is always boarded over the same as a plain vault, without any respect to the other, which is afterwards ribbed and boarded so as to make out the regular surface.

Timbers inserted in walls, and at returns, or angles, are joined together where the magnitude of the building or exposure to strain may require. There are three denominations, viz. *bond timber*, *lintels*, and *wall-plates*.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Flooring is supported by one or more rows of parallel beams, called *naked, or carcase flooring*, and is denominated either single or double. During the construction of the building, the flooring, if not supported by walls or partitions, must be shored. The framing of flooring, whether single or double, depends upon the magnitude of the building, the horizontal dimensions of the apartments, or the stress with which the surface of the boarding is likely to be affected. When the flooring is intended to be very stiff and firm, it is necessary to introduce truss girders. Naked flooring, for ball-rooms, should be framed very strong, and the upper part contrived with a spring, to bend with the impression of the force, while the lower part, which sustains the ceiling, remains immovable.

Partitions are constructed of a number of pieces of timber, called *scantling*, placed vertically, at a specified distance from each other, dependent on the purposes for which it is intended to answer. If to support girders, they should be trussed, and afterwards filled in with parallel pieces, called *studs*.

The framing ought to be so contrived, as to supersede the necessity of hanging up the floor, in whatever situation the doors may be placed. Truss partitions are also of the greatest utility in supporting floors which are above them.

The rafters which support the covering in a roof are sustained by one, two, or several pieces of framing, called a *pair of principals*, placed at right angles to the ridge of the roof. In roofing, many ingenious contrivances are resorted to, their application depending upon the pitch of the roof, the number of compartments into which it may be divided, and the introduction of tie-beams. In cases where apartments are required to be within the framing of the roof, and it is inconvenient to introduce tie-beams, the sides of the roof may be prevented from descending, by arching them with cast-iron, or trussing them with wood in the inclined planes of their sides. To restrain the pressure of the rafters, which would be discharged at the extremities of the building, a strong wall-plate, well connected in all its parts, must be introduced, to act as a tie, and prevent the lateral pressure from forcing out the walls.

In this construction, as well as in the former, the rafters would have a tendency to become hollow, so that it is necessary, in order to counteract this tendency, to introduce straining beams at convenient heights; and if it be requisite to occupy very little space by the wood-work, cast-iron

arches, abutting upon each other, and screwed with their planes upon the upper sides of the rafters, are best adapted for the purpose. If this and the former principle were adopted, the combined effect would be very great.

We shall now present the reader with a few practical observations.

Timber, except it stand perpendicular to the horizon, is much weakened by its own weight. The bending of timber is nearly in proportion to the weight laid on it. No beam ought to be trusted for any long time, with above one-third or one-fourth part of the weight it will absolutely carry; for experiments prove, that a far less weight will break a piece of timber when hung to it a considerable time, than is sufficient to break it when first applied.

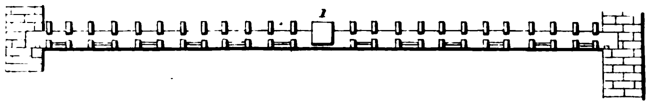
The strain occasioned by pulling timber in the direction of its length, is called *tension*. It frequently occurs in roofs, and is therefore worthy of consideration.

The absolute strength of a fibre, or small thread of timber, is the force by which every part of it is held together, and is equal to the force that would be required to pull it asunder. The force required to tear any number of threads asunder, is proportional to that of their sum; but the areas of the sections of two pieces of timber, composed of fibres of the same kind, are as the number of fibres in each; therefore, the strength of the timber is as the areas of the sections. Hence all prismatic bodies are equally strong; that is, they will not break in one part rather than in another.

Bodies which have unequal sections, will break at their smallest part; therefore if the absolute strength required to tear a square inch of each kind of timber be known, we shall be able to determine the strength of any other quantity whatever.

The wood next to the bark, commonly called *white* or *blea*, is also weaker than the rest: and the wood gradually increases in strength as we recede from the centre to the blea.

The heart of a tree is never in its centre, but always nearer to the north side, and on that side the annual coats of wood are thinner. In conformity to this, it is a general opinion among carpenters, that that timber is strongest whose annual plates are thickest. The *Tracheæ*, or *air-vessels*, are weaker than the simple ligneous fibres. These air-vessels make the separations between the annual plates, and are the same in diameter, and number of rows, in all trees of the same species; consequently, when these



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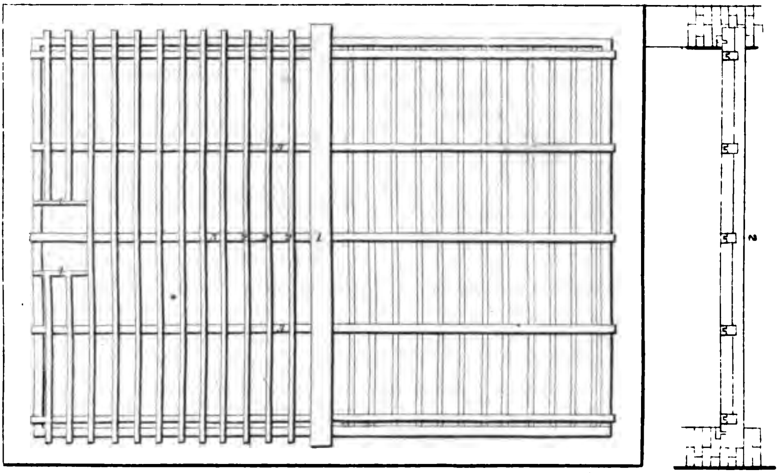

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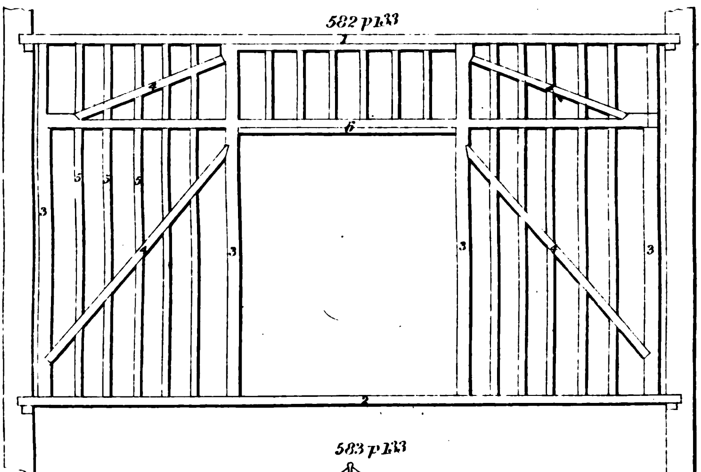

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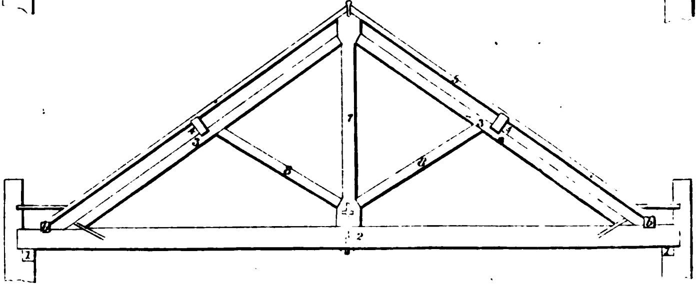


are thicker, they contain a greater proportion of the simple ligneous fibre.

The wood is stronger in the middle of the trunk than at the springing of the branches, or at the root; and the wood of the branches is weaker than that of the trunk.

The part of the tree towards the north, in the European climates, is the weakest, and that of the south side the strongest: and the difference is most remarkable in hedge-row trees, and such as grow singly.

All description of wood is more tenacious while green; and loses very considerably by drying, after the tree is felled.

We shall now conclude these remarks with the following useful problem.

Fig. 580. To cut the strongest beam possible out of a round tree whose section is a given circle. Let *a b c d* be the section of the tree; draw the diameter *c b*, divide it into three equal parts, *e* and *f*, and from one of them, as *f*, draw *f a* perpendicular to the diameter *c b*; draw *a b* and *a c*,—*b d* and *d c*, and *a b c d* is the strongest piece that can be cut out of the tree. From this it is manifest, that the strongest beam which can be cut out of a round tree, does not contain the most timber, for the greatest rectangle that can be inscribed in a circle is a square, and therefore the square *g h i k* is greater than the rectangle *a b c d*, and yet is not the strongest.

Fig. 581. Plan of a floor.—1 Girder resting upon the walls.—2. Bridging joists.—3. Binding joists.—4. Trimmers.

Nos. 1 and 2, sections of the floor.

Fig. 582. A trussed partition with an opening in the middle for folding doors.—1. Head.—2. Sill.—3. Posts.—4. Braces.—5. Studs.—6. Door-head.—This partition, as may be seen, supports itself.

Fig. 583. A simple trussed roof.

DEFINITIONS.

Wall-plates; pieces of timber laid on the wall, in order to distribute equally the pressure of the roof, and to bind the walls together. They are sometimes called *raising-plates.*

Tie-beam; a horizontal piece of timber, connected to two opposite principal rafters; it answers a two-fold purpose, viz. that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the rooms below. When placed above the bottom of the rafters, it is called a *collar-beam.*

Principal-rafters; two pieces of timber in the sides of the truss, supporting a grated frame of timber over them, on which the covering or slating rests.

Purlines; horizontal pieces of timber notched on the principal rafters.

Common rafters; pieces of timber of a small section, placed equidistantly upon the purlines, and parallel to the principal rafters: they support the boarding to which the slating is fixed.

Pole-plates; pieces of timber resting on the ends of the tie-beams, and supporting the lower ends of the common rafters.

King-post; an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam: this prevents the tie-beam from sinking in the middle.

Struts; oblique straining pieces, framed below into the king-posts, or queen-posts, and above into the principal rafters, which are supported by them; or sometimes they have their ends framed into beams, that are too long to support themselves without bending, they are often called *braces.*

Other pieces of timber are introduced in roofs of a greater span; which we shall here describe.

Queen-posts; two upright pieces of timber, framed below into the tie-beam, and above into the principal rafters; placed equidistantly from the middle of the truss, or its extremities.

Puncheons; short transverse pieces of timber, fixed between two others for supporting them equally; so that when any force operates on the one, the other resists it equally; and if one break the other will also break. These are sometimes called *studs.*

Straining-beam; a piece of timber placed between two others, called *queen-posts,* at their upper ends, in order to withstand the thrust of the principal rafters.

Straining-cill; a piece of timber placed upon the tie-beam at the bottom of two queen-posts, in order to withstand the force of the braces, which are acted upon by the weight of the covering.

Camber-beam; horizontal pieces of timber, made on the upper edge sloping from the middle towards each end in an obtuse angle, for discharging the water. They are placed above the straining-beam in a truncated-roof, for fixing the boarding on which the lead is laid: their ends run three or four inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead.

Auxiliary rafters; pieces of timber framed in the same vertical plane with the principal rafters, under, and parallel to them, for giving additional support. They are sometimes called *principal braces,* and sometimes *cushion rafters.*

Joggles; the joints at the meetings of struts, with king-posts, queen-posts, or principal rafters; or at the meeting of principal rafters with king and queen-posts: the best form is that which is at right angles to the struts.

Cocking, or Cogging; the particular manner of fixing the tie beams to the wall-plates.

There are a variety of roofs differing in form, according to the nature of the plan, and the law of the horizontal and vertical sections.

The most simple form of a roof is that which has only one row of timbers arranged in an inclined plane, and throws the rain entirely on one side. This description of roof is termed a *shed-roof, or lean-to.*

If the plan of the roof be a trapezium, and the tops of the walls properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge; consequently, the sides, instead of being planes, are made to wind, in order to have the summit parallel to the horizon; but the best plan is, to make the sides of the roofs planes, enclosing a level space or flat, in the form of a triangle or trapezium, at the summit of the roof. Roofs which are flat on the top, are said to be *truncated:* they are chiefly employed with a view to diminish the height, so as not to predominate over that of the walls.

If all the four sides of the roof are formed by inclined planes, it is said to be *hipped,* and is therefore called a *hipped-roof;* and the inclined ridges, springing from the angles of the walls, are called *hips.*

Roofs on circular bases, with all their horizontal sections circular, the centres of the circles being in a straight line, from the centre of the base perpendicular to the horizon, are called *roofs of revolution* or *revolved-roofs.*

When the plan of the roof is a regular polygon, circle, or an ellipsis, horizontal sections being all similar to the base, and the vertical section a portion of any curve, which is convex on the outside, the roof is called a *dome.*

In roofs of rectangular buildings, when a saving of expense is of consequence, instead of a lead flat, which must be covered with lead or copper, a valley is introduced, which makes the vertical section in the form of the letter M, or rather an inverted W; hence it has obtained the name of *an M roof.*

The *pitch* of a roof, or the angle which its inclined side forms with the horizon, is varied according to the climate and the nature of the covering.

The inhabitants of cold countries make their roofs very high; and those of warm countries, where it seldom rains or snows, very flat. But even in the same climate the pitch of the roof is greatly varied. Formerly the roofs were made very high, probably with the notion that the snow would slide off easier; but where there are parapets, a high roof is attended with very bad effects, as the snow slips down and stops the gutters, and an overflow of water is the consequence; besides, in heavy rains, the water descends with such velocity, that the pipes cannot convey it away soon enough to prevent the gutters from being overflowed.

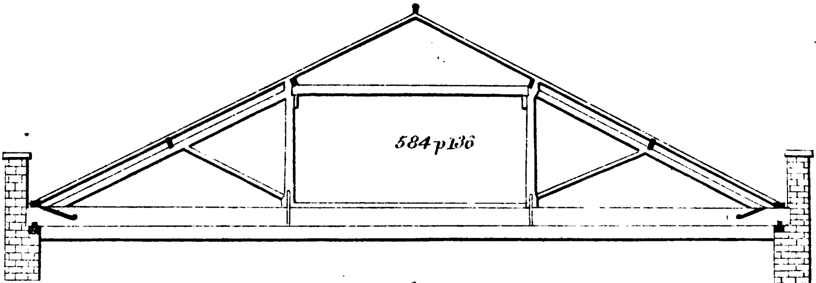
The height of roofs at the present time is very rarely above one-third of the span, and should never be less than one-sixth. The most usual pitch for slates is that when the height is one-fourth of the span, or at an angle of 26½ degrees with the horizon. Taking this as a standard, the following table will show the degree of inclination which may be given for other materials :—

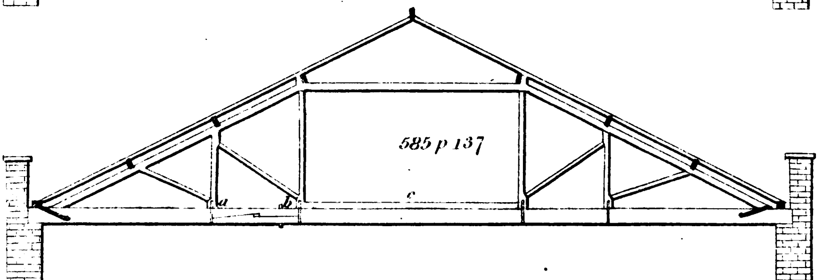
Kind of covering.	Inclination to the horizon in degrees. Deg.	Min.	Height of roof in parts of span.	Weight upon a square of roofing.
Copper or lead........	3	50	$\frac{1}{48}$	copper 100; lead 700
Slates large...........	22	0	$\frac{1}{5}$	1120
Ditto ordinary........	26	33	$\frac{1}{4}$	from 900 to 500
Stone Slate...........	29	41	$\frac{2}{7}$	2380
Plain tiles............	29	41	$\frac{2}{7}$	1780
Pan-tiles.............	24	0	$\frac{2}{9}$	650
Thatch of straw, reeds	45		$\frac{1}{2}$	

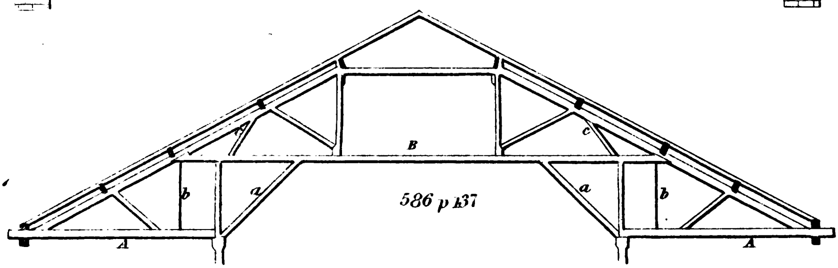
A roof for a span of from 20 to 30 feet may have a truss of the form shown in Fig. 583. Within this limit, the purlines do not become too wide apart, nor the points of support of the tie-beam.

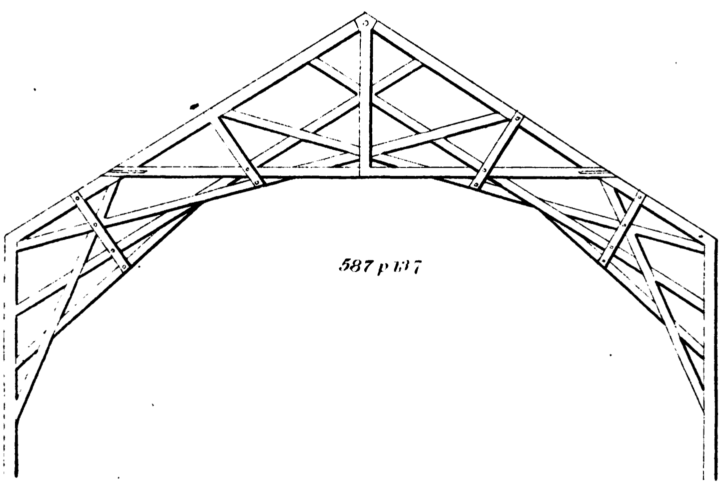
For spans exceeding 30 feet, and not more than 45 feet, the truss shown in Fig. 584 is well adapted. Each purline is supported, consequently, there are no cross strains on the principal rafters; and the points of support divide the tie-beams into three comparatively short bearings. The sagging, which usually takes place from the shrinking of the heads of the queen-posts, may be avoided by letting the end of the principal rafter abut against the end of the straining

From 584 to 587.









beam A, and notching pieces and bolting them together in pairs at each joint.

When the span exceeds 45 feet, and is not more than 60 feet, the truss shown in Fig. 585 is sufficiently strong for the purpose, and leaves a considerable degree of free space in the middle. For this span the tie-beam will most likely require to be scarfed, and as the bearing of that portion of the tie-beam between *a* and *b* is short, the scarf should be made there. The middle part of the tie-beam may be made stronger by bolting the straining cill *c* to it.

It often occurs, that the centre aisles or naives of churches are higher than the side aisles; a similar effect, as when the tie-beam continues through, may be produced by connecting the lower beams to the upper one, by means of braces, so that the whole may be as a single beam. To illustrate this mode of construction, we have given a design for a roof of a church, somewhat similar to St Martin's in the fields, London.

Fig. 586, the lower ties, A A, are so connected with the principal tie-beam, B, by means of the braces, *a*, *a*, that the foot of the principal rafters, *c*, *c*, cannot spread without stretching the tie-beam, B. The iron rods, *b*, *b*, perform the office of king-posts to the ties, A, A, and are much better than timber, in consequence of the shrinkage, which in this situation would be very objectionable.

Fig. 587 is a design for a roof of a church, or other building, requiring a semicircular arched ceiling.

Domes derive their names according to the plans on which they are built, circular, elliptical, or polygonal: of these, the circular may be spherical, spheroidal, ellipsoidal, hyperboloidal, paraboloidal, &c. Those which rise higher than the radius of the base, are called *surmounted domes;* those that are of a less height than the radius, *diminished*, or *surbased;* and such as have circular bases, *cupolas*. The most usual form for a dome is the spherical, in which case the plan is a circle, and the section a segment of a circle.

The top of a large dome is often finished with a lantern, supported by the framing of the dome.

The interior and exterior forms of domes are seldom alike, and in the space between them, a staircase to the lantern is usually made. According to the space left between the external and internal domes, the framing must be designed. Sometimes the framing may be trussed with ties across the opening; but generally the interior dome rises so high that ties cannot be obtained.

Fig. 588. No. 1, shows the construction of a dome without ties. This is the most simple method, and one which is particularly applicable to domes of ordinary dimensions. This example consists in placing a number of curved

ribs, so that the lower ends stand upon and are well framed into the kirb at the base, and the upper ends meet at the top, or are framed into the upper kirb on which the lantern is placed.

When it occurs, as it generally does, that the pieces are so long and so much curved, that they cannot be cut out of timber without being cut across the grain, so much as will weaken them, they should be put together in thicknesses, with the joints crossed, and well bolted together.

No. 2, shows the ribs fixed, and bolted together, with horizontal rafters to receive the boarding on the exterior, and the laths on the interior. These ribs should be placed about two feet, or two feet six inches apart at the base, and be composed of three or four thicknesses of one and a half inch-deal, about 11 or 12 inches wide, which, when carefully bolted together with the joints judiciously broken, will stand exceedingly firm and well.

To construct the ribs of a spherical dome, with eight axal ribs, and one purline in the middle.

(Fig 589.) No. 1. Let A B C D E be the plan of half the dome, which divide into four equal parts at B C D and E, these points of division will mark the centre of the back, or convex sides of the ribs. This being done, let B *b*, C *c*, D *d*, be the plans of these ribs, with the points of division in the centre. F, G, H, I, K, are the seats of the upper ends of the ribs; on the upper kirb draw *x y*, No. 2, parallel to A E, then from the different seats of the ribs on the plan draw perpendiculars cutting *x y*. Draw the cill, *x y*, its intended thickness, and complete the elevation of the front and back ribs. The front ribs are quadrants, forming a semicircle on the upper side of the wall-plate, which, of course, is the diameter. The curves of the sides of each of the other ribs are the quadrants of an ellipsis of the same height with the front rib. Place the purlines in their intended situation, and having drawn the elevation and plan, as shown by the dotted line, the construction is complete.

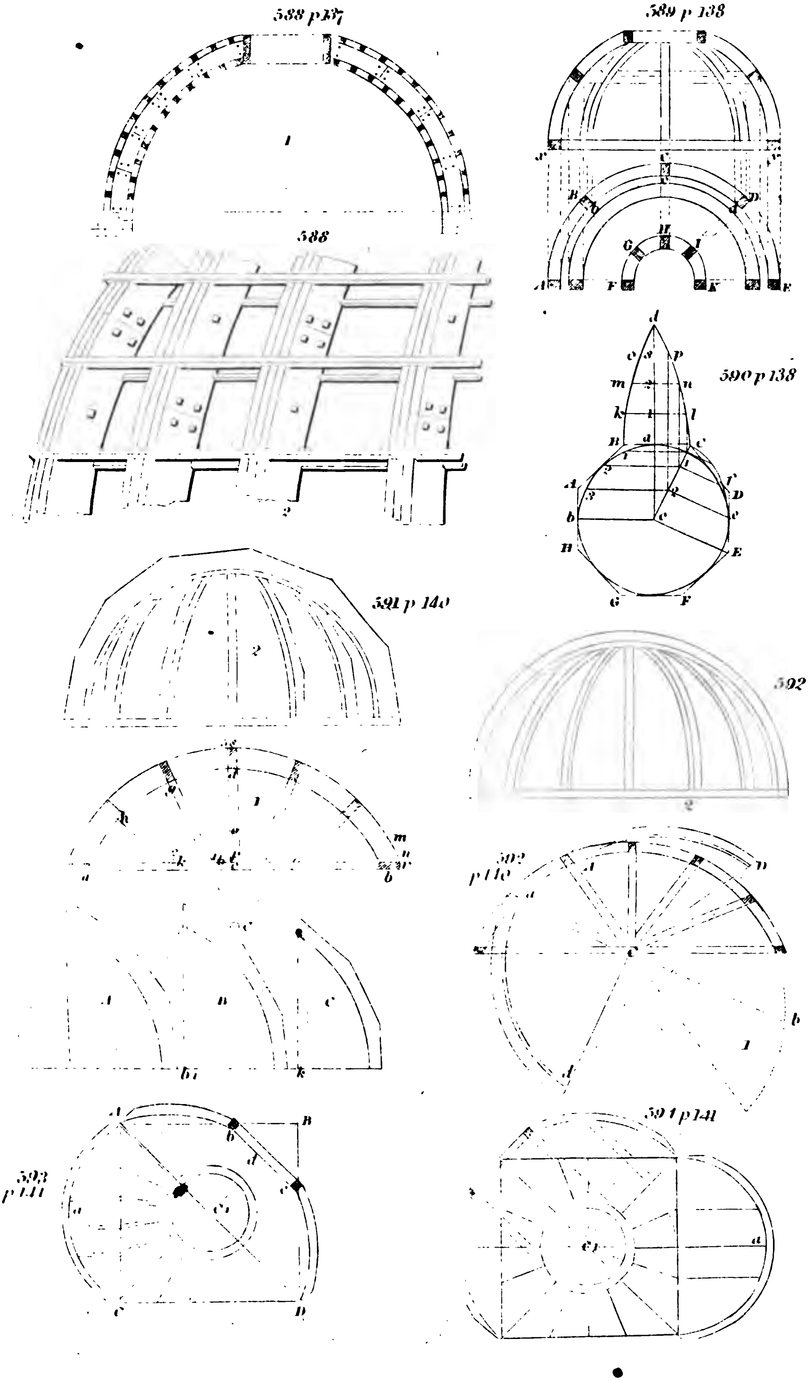
The ribs of an elliptical dome are found precisely on the same principle.

Given the plan of a polygonal dome, and one of the axal ribs, at right angles to one of the sides, to find the curve of the angle rib and the covering.

Fig. 590. Let A, B, C, D, E, F, G, H, be the plan of an octangular polygonal dome, and *c a b* the given rib; produce *c a* to *d*, divide the curve line *a* B A *b* into any number of equal parts, the more the better, in this case four, 1, 2, 3, *b*, which extend on the line *a d;* the first from *a* to 1, the second from 1 to 2, &c.: from the points of division, 1, 2, 3, *b*, draw lines parallel to B *e*, cutting C *c*, and from these points draw lines, parallel to *c d*, or at right angles to B *e*, and through the points, 1, 2, 3, draw *k l*, *m n*, *o p*, and tracing a curve through the points *d*, *p*, *n*, *l* C, and making *d o m k* B similar, then the space comprehended between the curve lines *d* B *e;* and the side B C of the plan, will give the form of the whole covering, for each side of the dome.

To find the hip-line of the angle-rib, whose base is C *c*.

Draw C E, 2 *e*, 1 *f*, at right angles to *c c*, and make C E equal to *c b*,


588 p 137
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589 p 138
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593 p 140
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2 e equal 2 3, and 1 f equal to 1, 2, &c. and trace the curve through these points, and it will give the angle-rib.

The method of covering spherical domes is, to suppose them polygonal, and the principle the same as the foregoing operation for an octangular dome.

A *niche*, is carpentry, is the wood-work to be lathed over for plastering. The general construction of niches is with cylindrical backs and spherical heads called *cylindro-spheric niches*; the execution of which depends upon the principles of spheric sections.

As every section in a sphere is a circle, and that section passing through its centre is equal, and the greatest that can be formed by cutting the sphere; it is evident, that if the head of a niche is intended to form a spherical surface, the ribs may be all formed by one mould, whose curvature must be equal to that of the greatest circle of the sphere; viz. one passing through its centre; but the same spherical surface may, though not so eligible, be formed by ribs of wood, moulded from the sections of lesser circles, in a variety of ways.

The reason why these latter spherical surfaces are not so eligible as those of greater circles is, because their disposition for sustaining the lath is not so good, and the trouble of moulding them to different circles, and of forming the edges according to different bevels, in order to range them in the spherical surface, is very great, compared with those made from great circles.

The disposition of the ribs of niches is generally in a vertical plane, parallel to each other, or intersecting each other in a vertical line. When the line of intersection passes through the centre of a sphere, all the ribs are great circles; but if the line of intersection does not pass through the centre of the sphere, the circles which from the spherical surface are all of different radii. When the ribs are fixed in parallel vertical planes, their disposition is either parallel to the face of the wall, or parallel to a vertical plane, passing through the centre of the sphere, perpendicular to the surface of the wall; but this method is not so eligible for the purposes of lathing.

Another method is, by making the planes of the ribs parallel to the horizon: this is not only attended with great labour in workmanship, but is incommodious for lathing. The various positions in which the ribs of a niche may be placed, are very numerous; but the regular positions, already

enumerated, ought to be those to which the carpenter should direct his attention.

To get out the ribs for the head of a niche, all of them being in vertical planes passing through the centre of the sphere.

Fig. 591, No. 1. From the centre C draw the ground-plan of the ribs, and set out as many ribs upon the plan as you intend to have in the head of the niche. With the foot of your compasses in C, and from the ends of each rib, at *k* and *l*, draw the small concentric dotted circles round to the centre rib, at *o* and *p*, and draw *o m*, and *p n*, parallel to *a b*, the face of the wall; then from *r* round to *s* on the plan is the length and sweep of the centre tib to stand over; and from *n* round to *s* the length and curve of the rib that stands from *b* to *g*; and from *m* round to *s*, the curve of the shortest rib, that stands from *k* to *h* on the plan.

How to find the bevel of the ends of the back ribs against the front rib.

The back ribs are laid down distinct by themselves, at A B and C from the plan. Take *b* 1, in No. 1, and set it to *b* 1, at B, draw the perpendiculars, and when they intersect the rib, it will show the bevel required. The same operation being done to C, the bevel is found in the same manner.

The places of the back ribs when fixed upon the front rib are ascertained by drawing perpendiculars, and completing the elevation of the niche No. 2 from the plan.

To find the radius of curvature of the ribs of a spherical niche, when the ribs all meet in a vertical line, which divides the front rib into two equal parts.

Fig. 592, No. 1. Complete the circle, of which the inside of the plan is an arc; produce the middle line of the plan of any rib, as of *a b*, to meet the opposite side of the circumference in *b*; on the whole line *a b*, as a diameter, describe a semicircle, and from the point *c*, when the ribs intersect, draw a perpendicular to *c d*, to meet the arc *a d* at *d*, which arc is the curve of the rib, whose seat is *d*. The other rib, as A D, is found in the same manner. No. 2 is the elevation of the niche.

Pendentive cradling, is a cove bracketing, springing from the rectangular walls of an apartment upwards to the ceiling, so as to form the horizontal part of the ceiling into a complete circle or ellipsis.

The proper criterion for such bracketing, if the walls are out by horizontal planes through the coved parts, is, that all the sections through such parts will be portions of circles, or of ellipses, and have their arcs proportioned to the sides of the apartment, so that each section will be a compound figure. Besides having four curvilinear parts, it will have four other parts, which are portions of the sides of the rectangular apartment: and the axis of the ellipsis will bisect each side of the rectangle.

Fig. 593. Let A B C D be the plan of a room, or stair-case, to be bracketed, so as to form the surface of a pendentive ceiling; and let A b c D be the section across the diagonal; it is required to find the curvature of the springing ribs?

Draw C d perpendicular to A C, meeting A C, take the distance from C to the line A C, and set it from C on the line C B, and from this point draw a perpendicular to meet the curve A b c D of the diagonal rib; make the versid sine of the segment A b C equal to this perpendicular, and describe the segment A l C, which is the springing line required. If from the centre C an arc be described, with a radius equal to the length of the seat of a rib, to meet the seat of the diagonal rib A D; and, if from the point of meeting a perpendicular be drawn to meet the curve A b, the portion of the arc of the diagonal rib, intercepted between A and the perpendicular, will give the length of the rib, corresponding to the seat which was taken.

Fig. 594. The diagonal rib is a semicircle: the operation is exactly the same, and may be described in the same words.

MENSURATION OF CARPENTERS' WORK.

All large and plain articles in which an uniform quantity of materials and workmanship is expended, are generally measured by the square of 100 superficial feet.

Piles used in the foundations are valued at per piece, and driven by the foot run, according to their diameter, and the quality of the ground.

Keepers and planking are measured by taking the superficial contents in yards or squares.

Plain centreing is measured by the square; but as the ribs and boarding are two different qualities of work, they ought to be measured and valued separately; one dimension of the boarding being taken by girting it round the arch, the other being the length of the vault.

Centreing for groins should be measured and valued as common centreing; but in addition thereto, the angles should be paid for by the foot run, that is, the ribs and boarding ought to be measured and valued separately, according to the exact superficial contents of each; and the angles by the lineal foot for workmanship, in fitting the rib and boards, and for the waste of wood occasioned by the operation.

Wall-plates, lintels, and bond-timbers, are measured by the cubic foot, under the denomination of fir-in-bond.

Naked flooring may either be measured by the square, or by the cubic foot, according to the description of the work, and the quantity of timber employed. In forming an estimate of its value, it should be observed, that in equal cubic quantities of small and large timbers, the small timbers will have

more superfices than the large ones, and, therefore, the saving will not be in a ratio with the solid contents; consequently the value of the workmanship will not follow the cubic quantity, or said ratio. The difficulty of handling timbers of the same length increases with the weight or solidity, as the greater quantity requires greater power to handle it, and consequently more time.

In naked flooring, where girders are introduced, the uniformity of the work is interrupted by mortises and tenons, so that the sum ascertained by the cubic quantity of the girders, at the same rate per foot as the other parts, is not sufficient; not only on account of the great difference of size, but the great disparity in the quantity of workmanship, occasioned by its being cut full of mortises to receive the tenons of the binding-joists; the best method, therefore, to value the labour and materials is, to measure and estimate the whole by the cubic quantity, and allow an additional rate upon every solid foot of girders; or, if the binding-joists are not inserted in the girders, at the usual distances, a fixed price for every mortise and tenon, in proportion to their size, which will keep a ratio with the area of the end of the girder.

Partitions may be measured by the cubic feet; but the cills, top-pieces, and door-heads, should be measured by themselves, according to the solid quantity, at an additional rate; because, both the uniform solidity, and the uniform quantity of workmanship are interrupted by them. In trussed partitions, the braces should be rated by the foot cube, at a superior price to that of the quarterings, for the trouble of fitting the ends of the uprights upon their upper and lower sides, and for forming the abutments at the ends.

The timbers in roofing should be measured by the cubic foot, classed as the difficulty of execution, or as the waste occasioned, may require.

Battening to walls is best measured by the square, according to the dimensions and distances in the clear of the battening.

It would be endless to enumerate the various methods of measuring each particular species of carpenters' work; the leading articles only need be noticed.

When the shell of a building is finished, that is, previous to the floors being laid, or the ceilings lathed, all the timbers should be measured, that no doubt may arise as to the actual scantlings of the timbers, or of the description of the workmanship. In taking dimensions it must be observed that,

all pieces which have tenons, must be measured to the extremities of the tenons.

It is impossible to determine on any proper rate, including both materials and workmanship, as the one may be stationary, while the other is variable. With respect to materials, the value of any quantity may be easily ascertained, whatever be the price per load; but the difficulty is far greater in fixing proper rates of workmanship; however, were the time of executing every species of work known, there would be no difficulty in establishing certain uniform quantities, which would give the real value.

JOINERY,

Is the next branch of art which comes under our consideration, and comprises the practice of employing wood in the external and internal finishings of houses.

In the execution of this branch of building, it is almost unnecessary to observe that, as joinery is employed principally by way of decoration, and is liable to close inspection, it is one of the departments which demands the strictest care and attention in the workmen; and it requires the greatest ingenuity, skill, and experience, to become fully master of every subject under the joiner's consideration.

The first and most important thing to be attended to, is the judicious selection of materials; as, without a strict observance of this particular, the care, ingenuity, and exertions of the workman will be wholly frustrated.

As the temperature of the atmosphere has a great influence on wood, and more particularly in the winter season, it would be advisable to put that which is to be used in fine work over an oven for a day or two. In the different descriptions of joint used by the joiner, a hot tenacious liquid, called *glue*, is almost universally used, and when applied, the two surfaces of the wood, which have been previously rendered smooth, are rubbed together until the glue is nearly all forced out. One piece is then set to its situation with respect to the other.

For outside work, such as gates, doors, &c. white-lead is used in all the joints.

When a frame, consisting of several pieces, is required, the mortises and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by the assistance of an instrument called a *cramp*.

The operation of rendering a rough surface smooth, by taking away the superfluous wood, is called *planing;* and the tools used for this purpose are called *planes.*

The planes used by joiners in the primary operation of their work are called *jack-planes, trying-planes, long-planes,* and *smoothing-planes;* the respective uses of which are as follow:—The jack-plane is used for taking away the rough occasioned by the saw, and removing all superfluous and other uneven parts. The trying-plane more particularly to bring the surface perfectly level and true: the long-plane succeeds, when the surface is long and is required to be very straight, as in jointing long boards for the purpose of gluing them together; and the smoothing-plane is used to smooth and clean off the work.

In addition to the above, termed *bench-planes,* others are occasionally used in forming any kind of prismatic surfaces, viz. *rebating-planes, grooving-planes, moulding-planes, &c.*; under which head is included the *fillister* and *plough.*

Rebating-planes are used for cutting out rebates, a kind of half groove, upon the edge of a board, or other piece of wood, formed by taking down or reducing a small part of the breadth of the board to half, more or less, of the general thickness. By this means, if a rebate be cut on the upper side of one board, and the lower side of another, the two may be made to overlap each other, without making them any thicker at the joint.

Rebates are also used for ornamenting mouldings, and for many other purposes in joiners' work. The planes for cutting them are of different kinds, some having the cutting edge at the side of the iron and stock; others at the bottom edge of the iron and the face of the stock; and others cutting in both these directions. The former are used to smooth the side of a rebate, and therefore are called *side rebating-planes;* the others for smoothing the bottom. A third sort of rebate-planes, called a *fillister,* is used for sinking or cutting away the edge of a piece of wood, to form the rebate, leaving it for the others to smooth the surfaces when cut.

The *moving fillister* is a rebating-plane having a ruler of wood, called the *fence,* fixed by screws, upon its face, in the direction of its length, and exactly parallel to the edge of the face; consequently, it covers part of the width of the cutting edge, and can be fixed at any required distance from the edge, to leave more or less of the cutting edge exposed, which will be the breadth of the rebate it will cut, because,

when used, the edge of the fence is applied against the edge of the piece to be rebated, and thus gauges the breadth its iron should cut away. The cutting-iron of this plane is not situated at right angles to the length of the stock, but has an obliquity of about forty-five degrees; the exposed side of the iron being more forward than the one next to the fence. By this obliquity the plane has a tendency or drift to run further into the breadth of the wood; but as the fence sliding against the edge prevents this, the drift always keeps the fence in contact with the piece without the attention of the workman: it also causes the iron to cut the bottom of the rebate smoother, particularly in a transverse direction to the fibres, or where the wood is cross-grained, or where the edge is perpendicular to the sides of the plane. It is chiefly used, however, to throw the shaving into a cylindrical form, and thereby make it issue from one side of the plane. Besides this iron, there is another of smaller dimensions, called the *tooth*, which precedes the other, to scratch or cut a deep crack in the width of the rebate, thus making the shaving, which the iron cuts up from the bottom, separate sideways from the rest of the wood. The *sash-fillister* differs in many particulars from the moving fillister: the fence is adapted to be moved to a considerable distance, not being fixed, as in the moving fillister, by screws upon the face, but sustained by two bars, fixed fast to it, passing through the two vertical sides of the stock at right angles to the sides: these bars, when set to their intended places, are tightened by small wedges. This kind of plane is usually employed to rebate narrow pieces of wood, such as are used in sashes; and the fence is applied against the opposite edge to that on which the rebate is to be formed.

The *plough* is a plane with a very narrow face, made of iron, fixed beneath a wooden stock, and projecting down from the wood of the stock; the edge of the cutting-iron being the full width of the groove required: it is guided by a fence with bars like the sash-fillister, and has also a stop to regulate the depth intended for the grooves.

Moulding-planes are those which have their faces and cutting edges curved to produce all the varieties of ornamental mouldings: they are known by the names of *snipe's-bills, side snipe's-bills, beads, hollows, rounds, ovolos,* and *ogees*. Of these there are a great variety of sizes, with which every good joiner is furnished.

The whole of these planes have their faces straight in the

direction of their length; but a section across the face is the impression or reverse of the moulding they are intended to make.

The tools employed in boring cylindric holes are a *stock* with *bits*, *gimlets*, and *brad-awls* of various descriptions and sizes. The tools used for paring the wood obliquely, or across the fibres, and for cutting rectangular prismatic cavities, are in general denominated *chisels;* those for paring the wood across the fibres being called *firmers*, or *paring-chisels*, and those for cutting mortises, *mortise-chisels*. The best paring-chisels are made entirely of cast steel. Chisels for paring concave surfaces, are called *gouges*.

Wood is generally divided or reduced by means of *saws*, of which there are several sorts; as the *ripping-saw*, for dividing boards into separate pieces, in the direction of the fibres; the *hand-saw*, for cross-cutting, or for sawing thin pieces in the direction of their length; the *panel-saw*, either for cross-cutting, or cutting very thin boards longitudinally; the *tenon-saw*, with a thick iron back, for making an incision of any depth below the surface of the wood, and for cutting pieces opposed to the length of the fibres; also a *sash-saw*, and a *dovetail-saw*, used much in the same way as the tenon-saw.

From the thinness of the plates of these three last-mentioned saws, it is necessary to stiffen them by a strong piece of metal called the back, which is grooved to receive the upper edge of the plate, fixed to the back, and which is thereby secured and prevented from crippling.

When it is required to divide boards into curved surfaces, a very narrow saw without a back, called a *compass-saw*, is used; and in cutting a very small hole, a saw of a similar description is used, called a *key-hole-saw*. Both of these description of saws are called *turning-saws*, and have their plates thin and narrow towards their bottoms, and each succeeding tooth finer.

The external and internal angles of the teeth of all saws are generally formed at one angle of 60 degrees, and the front edge teeth slope backwards in a small degree. The teeth of every description of saw, except turning-saws, are alternately bent on contrary sides of the plate, so that all the teeth on the same side are alike bent throughout the length of the plate, for the purpose of clearing the sides of the cut made by it in the wood. The foregoing are generally termed *edge-tools*.

When it is necessary to ascertain if an angle be exactly

square, or inclined to any number of degrees, a tool called a *square* is used, and in the latter instance, a *bevel* is set to the angle; when any piece is to be reduced to a parallel breadth or thickness, an instrument, called a *gauge*, formed of a square piece with a mortise, having a sliding bar, called a *stem*, running through it at right angles, and furnished with a tooth, projecting a little from the surface, is used; so that when the stock of the gauge is applied to the vertical side or edge of the piece, with the toothed side of the stem upon the horizontal surface, and is pushed and drawn alternately backwards and forwards by the workman, the tooth will make an incision from the surface into the wood, at a parallel distance from the edge to which the stock part is applied.

When a mortise is to be made in a piece of wood, the gauge used has two teeth. The construction of this gauge is the same as that before described, except that the tooth nearest the stock moves by means of a longitudinal slider in the stem, which is to be set at a distance from the other tooth, as occasion may require.

If a piece of wood is to be sawn across the fibres, a flat piece of wood, which has two projecting knobs, on opposite sides, one at each end, called a *side-hook*, is used, to keep the piece which has to undergo the operation of the saw steady; the knob at one end presses against the piece, while that at the other end is hooked to the bench. Two of these are necessary when the pieces are long.

When a piece of wood is required to be cut to a mitre, that is, to half a right angle, joiners use a trunk of wood with three sides, like a box that has neither ends nor top, the sides and bottom being parallel pieces, and the sides of equal height. Through each of the opposite sides, in a plane perpendicular to the bottom, and at the oblique angles of 45° and 135° with the planes of the sides, a kerf is cut; and another kerf is made with its plane at right angles to the two former. Into this trunk, termed a *mitre-box*, the piece to be cut is put, and the saw, guided by the kerfs, cuts the wood to the angle required.

In making a straight surface, a strip of wood called a *straight-edge*, which has one of its edges perfectly straight, is frequently applied, to detect the irregularities, and the piece is accordingly planed with the trying plane until the surface coincides with the straight edge.

To ascertain if the surface of a piece of wood be in one plane, the joiner takes two slips of wood, each straightened

on one edge, with the opposite edge parallel, and both pieces of the same height, and places them one at each end, across the board under operation; he then looks in the longitudinal direction of the board over the upper edges of the slips, and if the two edges and his eye be not in one plane, the upper parts are planed down until the piece is said to be *out of wind*, and the same term is applied to the slips, which are called *winding-sticks*. The operation of making the edge of a board straight is called *shooting*; and the edge so made is said to be *shot*.

From what has been here said of the application of the principal tools used by the joiner, we consider any further account of the primary processes unnecessary; we shall, therefore, proceed to lay before the reader the best methods in use of effecting some of the more difficult and particular operations.

To construct the surface of a portion of a cylinder with wood, when the fibres are at right angles to the axis of the cylinder, such as may be used in a circular dado, or the soffits of windows.

If the dimension of the cylindric surface, parallel to the axis, be not broader than a plank or board, this may be done by glueing several thicknesses of veneer upon each other; the first upon a mould, or upon brackets, with their edges in the surface of the proposed cylinder, parallel to its axis. This may be effected by means of two sets of brackets fastened to a board, one convex and of the curve intended, and the other concave of the curve of the exterior of the whole tkickness of veneers, or somewhat larger; this last bracket is then applied on the top of the veneers and fastened to the other bracket, and the veneers are then forced together by means of wedges between the concave bracket and the veneer. If this operation be carefully done, and the glue properly dried, the wedges may be slackened and the work will stand well, but it must be observed, that as the wood has a natural tendency to unbend itself, the curved surface, upon which it is glued, should be rather quicker than that intended to be made.

A *second* plan is to form a templet or cradle to the surface intended, and lay a veneer upon it; then to glue a number of blocks of wood upon its back, closely fitted to its surface, and the other joints to each other, the fibres of the veneer being parallel to those of the blocks.

A *third* method is to make a cradle and place the veneer upon it, confining one end: lay the glue between the

veneers with a brush, and fix a bridle across, confining its ends either by nails or by screws; open the veneers again, put glue a second time between each, and fix another bridle across them; and in this manner proceed to the other extremity.

A *fourth* plan is to cut a number of equidistant grooves across the back of the board, at right angles to its edges, leaving only a small thickness towards the face; then to bend this round a cradle with the grooves outwards, and fill the grooves with strips of wood, which, after the glue is quite dry, must be planed down level with the surface of the board. This may be stiffened by gluing strong canvass on the back.

To bend a board so as to form the frustrum of a cone, or any segmental portion of the frustrum of a cone, as the soffit of the head of an aperture.

When the envelope of the covering is found by the rule laid down under the article Masonry, page 104, vol. ii. and the mould is made with a thin piece of board, cut out the board intended to be bent, and run a number of saw kerfs, or grooves made by a plane, (which are preferable,) equidistant from each other, and tending to the centre, and having fixed it to a templet, made to the surface of a cone, finish it in the manner shown in the last method, for a cylinder.

To glue up the shaft of a column, supposing it to be the frustrum of a cone.

Prepare as many staves as the circumference may require, and let the joints of each be so managed as to fall in the fillets, which disposition will be stronger than if they were to fall in the middle of the flutes. Suppose eight pieces to be sufficient to constitute the shaft of a column: describe a circle to the diameter of each end; about each circle describe an octagon; from the concourse of each angle draw a line to the centre, then draw an interior concentric octagon, with each side parallel to the respective sides of the corresponding one, and the distance between these two octagons equal to the thickness of the staves; and thus the section of the staves will be found at each end, and consequently the bevels will be obtained throughout the whole length. In order to join the column, glue two pieces together, and when quite dry, glue in blockings to strengthen them; join a third piece to the former two, and secure it also by blockings. In this manner proceed to the last piece but one. In fixing the last piece, the blockings must be glued to the adjacent staves;

and their surfaces, on which the last stave is intended to rest, must be all in the same plane, that its back may rest firmly upon them. In closing up the remaining space, the part of the column that is glued together should be kept from spreading by confining it in a kind of cramp, or cradle, while driving the remaining stave to close the joints.

Instead of the foregoing mode, some joiners glue up the columns in halves and then glue them together. When an iron core is necessary to support a floor or roof, the column must necessarily be glued up in halves; in which case the two halves are to be dowelled together, and the joints filled with white-lead. Instead of a cramp, a rope is used, twisted by means of a lever. In bringing the two halves together, the percussive force of the mallet must be applied upon the middle of the surface of one half, while an assistant holds something steady against the middle of the other, that the opposition may be equal, and by this means the surfaces will be brought into contact, and form the joint as desired. In this operation pieces of wood ought to be inserted between the column and the rope.

Boards can be connected together at any given angle, either by pins or nails, mortise and tenon, or by indenting them together.

This last mode, from the sections of the hollows and projecting parts being formed like a dove's tail, is called *dovetailing*.

There are three sorts of *dovetailing*; viz. common, lap, and mitre. Common dovetailing shows the form of the projecting parts, as well as of the excavations made to receive them; lap dovetailing conceals the dovetail, but shows the thickness of the lap on the return side; and mitre dovetailing conceals the dovetail and shows only a mitre on the edges of the planes at the surface of the concourse; that is, the edges in the same plane, the seam or join being in the concourse of the two faces, making the given angle with each other.

Concealed dovetailing is particularly useful where the faces of the boards are intended to form a saliant angle; but when the faces form a re-entrant angle, common dovetailing is preferable.

There is another simple and expeditious manner of connecting the ends of boards together where the faces form a re-entrant, or internal angle, by means of a groove in the one, and a tongue in the other; and if the pieces be pre-

viously nailed so that the nails be not seen in the faces, this will answer every purpose of common dovetailing.

As various methods are employed in connecting pieces of wood so as to form an angle, we shall here present the reader with some of the best examples.

Figs. 595 and 596 are methods of connecting two pieces of wood so as to form two internal right angles.

Figs. 597, 598, 599, 600, 601, and 602, exhibit the joining of boards at an external angle.

In Figs. 598 and 599 the external angle, being that which is exposed to sight, is rounded or beaded.

Fig. 600 is the most common of mitres.

Fig. 601, a lapped mitre, which is much stronger than Fig. 600.

Fig. 602, a lapped and tongued mitre.

Fig. 603, dovetailing.

Fig. 604, secret dovetailing.

If several boards are required to be joined together to form a broad face, they are sometimes strengthened by fixing, with a tongue and groove, or mortise and tenon, another narrow piece across each end: the cross piece is termed a *clamp*, and the board thus constructed is said to be *clamped*.

The most simple description of door is constructed of several boards simply rebated together, or each edge ploughed and tongued; these are confined together by a transverse piece, called a *ledge* nailed across, from which the door derives the name of a *ledge-door*.

When strength, durability, and beauty are to be combined, a frame, joined by mortise and tenon, is constructed with one or more openings; and these openings are filled with pieces called *panels*, fitted into grooves, ploughed in the edges of the frame. The horizontal pieces of the framing are called, according to their situation, *top-rail*, *bottom-rail*, *lock-rail*, and *frieze-rail*. On the lock-rail the lock is either mortised in, or screwed on; and the frieze-rail is an intermediate rail between the top and middle rail. The extreme vertical pieces to which the rails are fixed are called *stiles;* and if there be any intermediate piece it is called a *mounting*.

Doors derive their names according to the manner in which they are framed and the number of panels they contain, as one, two, four, six, &c. panelled doors; and are further described by the moulding and description of panel.

Jib-doors are those which, when shut, are as much concealed as possible. They are used to preserve the uniformity of a room, or to save the expense of a corresponding door. Doors

ought to be made of the best materials, perfectly seasoned, and firmly put together; the mitres or scribings should be brought together with the greatest exactness, and the whole of their surfaces be perfectly smooth.

The mortising, tenoning, ploughing, and sticking of the mouldings, ought to be worked correctly to the gauge-lines; otherwise the door, when put together, will be out of truth, and occasion the workman a great deal of trouble, paring the different parts to make it appear satisfactory: the door will also loose much of its firmness, especially if the mortises and tenons require to be pared.

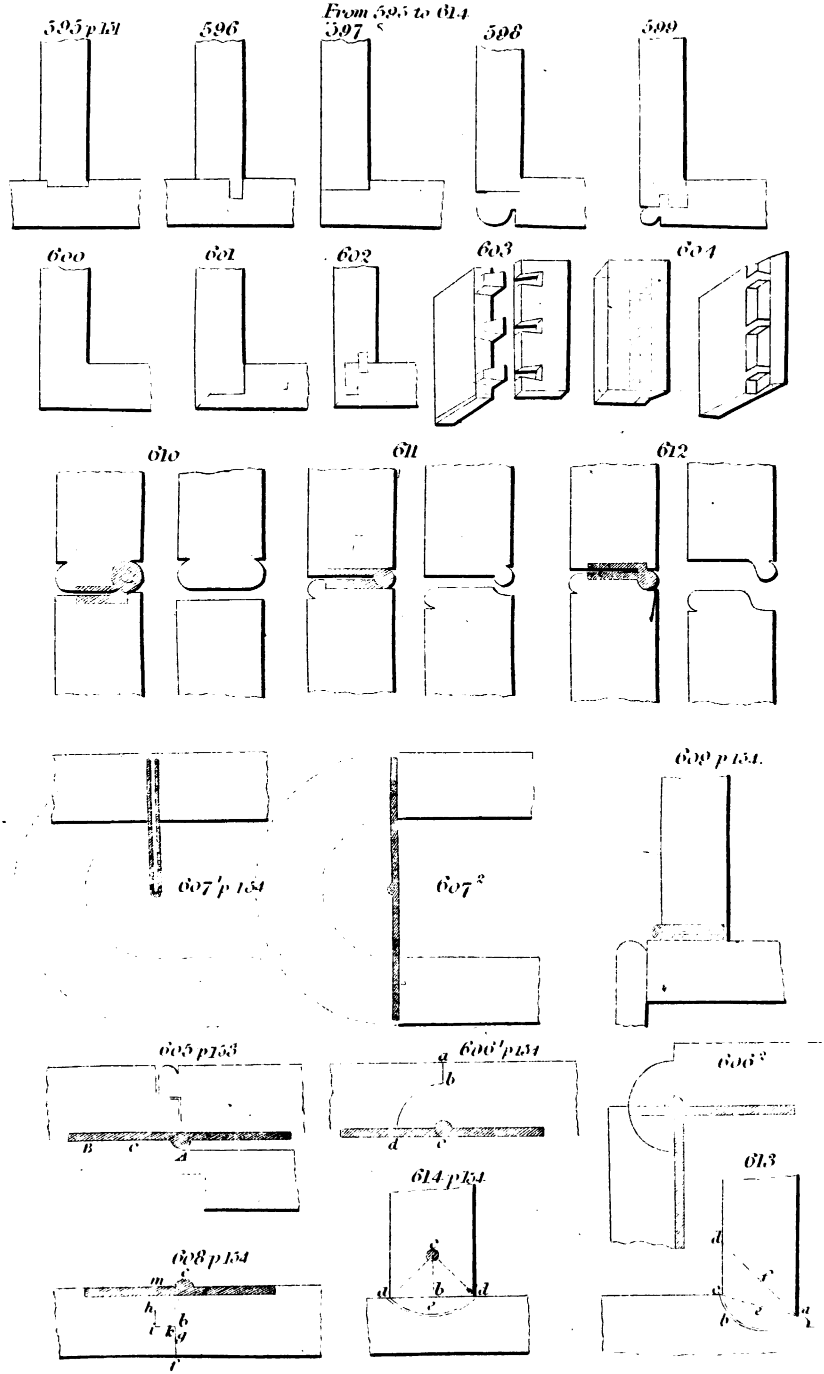
In bead and flush doors, make the work square, afterwards put in the panels, and smooth the whole off together; then, marking the panels at the parts of the framing to which they agree, take the door to pieces, and work the beads on the stiles, mountings, and rails. If the doors are double margin, that is, representing a pair of folding doors, the staff stile, which imitates the meeting-stiles, must be inserted into the top and bottom rails of the door, by forking the ends into notches cut in the top and bottom rails.

In the hanging of doors, the chief aim is to clear the carpet or ground; which may be accomplished by observing the following rules. First, let the floor be raised under the door, according to the intended thickness of the carpet; secondly, let the knuckles of the top and bottom hinges be so placed, that the top hinge hang, or project, about one-eighth of an inch over the lower; that is, if the hinge be let equally into the door and into the jamb, project a little beyond the surface of the door; but if the centre lie in the surface of the door, it must be placed at the very top, which is seldom done, except when the door is hung with centres. Thirdly, let the jamb on which the door hangs be fixed about an eighth of an inch out of the perpendicular, the upper part inclining towards the opposite jamb; and fourthly, let the inclination of the rebate be such, that the door shall, when shut, project at the bottom, towards the room, about an eighth of an inch.

These several methods, practised on so small a scale, are not perceptible; but, nevertheless, will throw the door, when opened, to a square sufficiently out of the level; that is, at least half an inch, when the height of the door is double the width.

Several kinds of rising hinges have been introduced for this purpose: some of the best, constructed of brass, are by no means objectionable, even to the best doors.

From 595 to 614



Before we proceed to the principles of *hanging* doors, we shall submit to the reader some information on the subject of *hinging* in general.

The placing of hinges depends entirely on the form of the joint, and as the motion of the door or closure is angular, and performed round a fixed line as an axis, the hinge must be so fixed that the motion be not interrupted: thus, if the joint contain the surface of two cylinders, the convex one in motion upon the edges of the closure, and sliding upon the concave one which is at rest on the fixed body, the motion of the closure must be performed on the axis of the cylinder, which axis must be the centre of the hinges. In this case, whether the aperture be shut or open, the joint will be close; but if the joint be a plane surface, it is necessary to consider upon what side of the aperture the motion is to be performed, as the hinge must be placed on the side of the closure where it revolves.

The hinge is made in two parts, movable in any angular direction, the one upon the other.

The knuckle of the hinge is a portion contained under a cylindric surface, and is common both to the moving part and the part which is at rest; the cylinders are indented into each other, and are made hollow to receive a concentric cylindric pin, which passes through them, and connects the moving parts together.

The axis of the cylindrical pin, is called *the axis of the hinge.*

When two or more hinges are placed upon a closure, the axis of the hinges must be in the same straight line.

The straight line in which the axis of the hinges are placed is called the *line of hinges.*

We shall now proceed to the principle of hanging doors, shutters, or flaps, with hinges.

The centre of the hinge is generally put in the middle of the joint, as at A, Fig. 605, but in many cases there is a necessity for throwing back the flap to a certain distance from the joint; in order to effect this, suppose the flap when folded back, were required to be at a certain distance from the joint, as B A, Fig. 605, divide B A in two equal parts at the point C, and it will give the centre of the hinge. The centre of the hinge must be placed a small degree beyond the surface of the closure, otherwise it will not fall freely back on the jamb, or partition. It must also be observed, that, the centre of the hinge must be on the same side as the rebate, or it will not open without the joint being constructed in a particular form.

To hang two flaps, so that when folded back, they shall be at a certain distance from each other.

This is easily accomplished by means of hinges having knees projecting to

half that distance, as appears from Fig. 607: this sort of hinge is used in hanging the doors of pews, in order to clear the moulding of the coping. Fig. 607, No. 2, shows the same hinge opened.

To make a rule joint for a window-shutter, or other folding flap.

Fig. 606, No. 1. Let *a* be the place of the joint, draw *a c* at right angles to the flap, shutter, or door, take *c*, in the line *a c*, for the centre of the hinge, and the plain part *a b*, as may be thought necessary; or *c*, with a radius, *c b*, describe the arch *b d*; then will *a b d* be the true joint. The kunckle of the hinge is always placed in the wood; because the further it is inserted, the more of the joint will be covered when it is opened to a right angle, as in Fig. 606, No. 2; but if the centre of the hinge were placed the least without the thickness of the wood, it would show an open space, which would be a blemish.

To form the joints of stiles, to be hung together, when the knuckle of the hinge is placed on the contrary side of the rebate.

Fig. 608. Let *c* be the centre of the hinge, *m i* the joint on the same side, *c b* the depth of the rebate in the middle of the thickness of the styles, perpendicular to *i m*, and *l f* the joint on the other side, parallel to *i m*; bisect *i l* at *k*, join *k c*, on *k c* describe a semicircle *c i k*, cutting *i m* at *h*; through the points *h* and *k* draw *h k g*, cutting *f l* at *g*; then will *f g*, *h m*, be the true joint.

Fig. 609 represents the common method of hanging shutters together, the hinge being let the whole of its thickness into the shutter, and not into the sash-frame. By this mode it is not so firmly hung as when half of it is let into the shutter, and half into the sash-frame; but the lining may be made thinner.

It may here be proper to observe, that the centre of the hinge must be in the same plane with the face of the shutter, or beyond it, but not within the thickness.

How to construct a joint for hanging doors with centres.

Fig. 614. Let *a d* be the thickness of the door, bisect it in *b*, draw *b c* perpendiular to *a o*, make *b c* equal to *b a*, or *b d*, or *c* the centre of the hinge, with a radius *c a*, or *c d*, describe an arc, *a e d*, which will give the joint required.

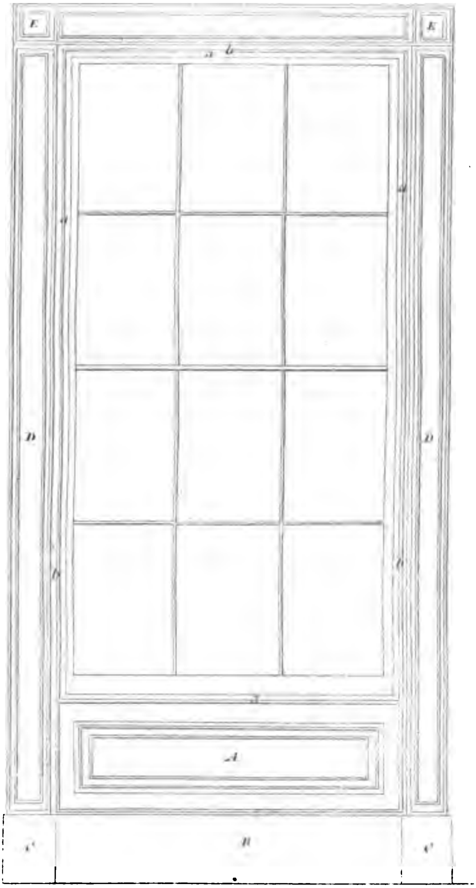
Another plan is represented in Fig. 613. Draw *a b* parallel to the jamb, meeting the other side in *b*, make *b d* equal to *b a*, and join *a d* and *a c*, bisect *a c* by a perpendicular *e f*, meeting *a d* in *f*, then *f* is the centre of the hinge.

Figs. 610, 611, and 612, exhibit different methods of hanging flaps, &c. These are so very simple, that by a little attention the reader will readily perceive their uses and manner of construction.

We shall now detail the construction of sash-frames, sashes, and shutters, and the manner of putting the several parts together.

Fig. 615, No. 1, the elevation; No. 2, the plan; and No. 3, the section of the same; showing the manner in which the different parts are connected.

615¹
p 154



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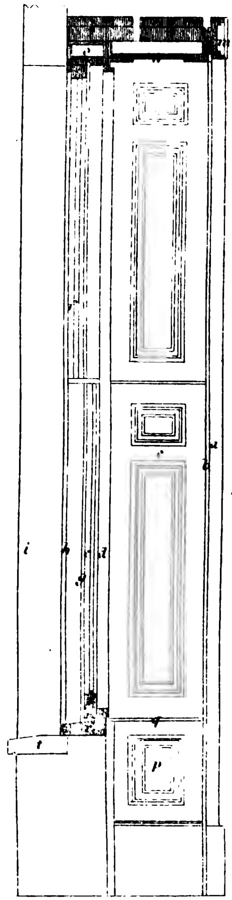

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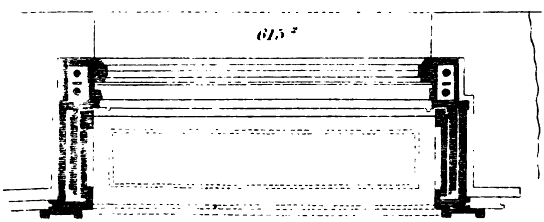

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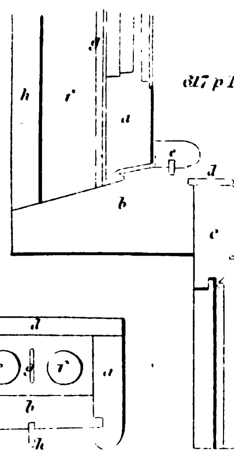

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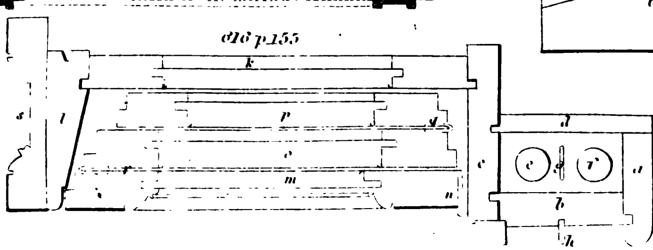


No. 1. A Back.—B Flush skirting, separated from the back by flush reeds, and showing the same depth of plinth as the blocks of the pilasters.—C C Blocks or plinths to pilasters.—D D Pilasters.—E E Patteras.—*a a a a* Inside bead of sash-frame.—*b b b* rounded edge of boxing-stile.

No. 2. Plan of sash-frame, shutters, pilasters, and the different parts are explained in the figures.

No. 3. *a* thickness of the pilaster or architrave; *b* the rounded edge of the boxing-stile; *c* the breadth of the shutter; *d* bead of the sash-frame; *e* under sash; *f* top ditto; *g* parting bead; *h* outside lining and bead. *i* the breadth of the reveal or outer brick-work; *k k* lintels made of strong yellow deal or oak; *l* the head of the ground; *m* the architrave or pilaster fixed upon the grounds; *n* the soffit, tongued into the top of the sash-frame-head; and, on the other edge, into the head of the architrave *m*; *o* the sash-frame-head; *p* the elbow; *q* capping; *r* sash-frame-cill; *s* sash-cill; *t* stone-cill.

The face of the pulley-stile of every sash-frame ought to project about three-eighths of an inch beyond the edge of the brick-work; that is, the distance between the face of each pulley-stile ought to be less by three-quarters of an inch than in the clear of the reveals on the outside; so that the face of the shutters ought to be in the same plane with the stone or brick-work on the outside.

Fig. 616 shows a plan of a sash-frame and shutter on the same principle as the foregoing, and which may be applied to a similar window.

As the thickness of the wall is here conceived to be less than in the foregoing example, another back-flap is introduced:—*a* the outside lining; *b* the pulley-stile; *c* the inside lining; *d* the back lining; *e f* the weights; *g* parting slip of weights; *h* parting bead to sashes; *i* inside bead; *k* back lining of boxing; *l* ground, or boxing-stile, grooved to receive the plastering; *m* front shutter hung to the inside lining, *c*, of the sash-frame by the hinge *n*; *o p* back flaps hinged together at *q*, and to the shutter at *r*; *s* architrave or pilaster.

Fig. 617 is a vertical section of the cill, &c. of the same sash-frame; *a* bottom rail of sash; *b* cill of the sash-frame; *c* back of recess of window; *d* coping bead, or capping let into the sash-frame cill; *e* inside bead, tongued on the top of the cill; *h* outside lining; *f* space for the top-sash to run in; *g* parting bead.

STAIRS.

This is one of the most important subjects connected with a joiner's art, and should be attentively considered, not only with regard to the situation, but as to the design and execution. The convenience of the building depends on the situation; and the elegance, on the design and execution of the workmanship. In contriving a grand edifice, particular attention must be paid to the situation of the space occupied by the stairs, so as to give them the most easy command of the rooms.

With regard to the lighting of a good staircase, a sky-light, or rather lantern, is the most appropriate; for these

unite elegance with utility, that is, admit a powerful light, with elegance in the design; indeed, where the staircase does not adjoin the exterior walls, this is the only light that can be admitted. Where the height of a story is considerable, resting places are necessary, which go under the name of *quarter-paces*, and *half-paces*, according as the passenger has to pass one or two right-angles; that is, as he has to describe a quadrant or semi-circle. In very high stories, which admit of sufficient head-room, and where the space allowed for the staircase is confined, the staircase may have two revolutions in the height of one story, which will lessen the height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building, so as to admit of fixed proportions.

The breadth of the steps ought never to be more than 15 inches, or less than nine; the height not more than seven, or less than five: there are cases, however, which are exceptions to all rule. When the height of the story is given in feet, and the height of the step in inches, you may throw the feet into inches and divide it by the number of inches the step is high, and the quotient will give the number of steps.

It is a general maxim, that the greater breadth of a step requires less height than one of less breadth: thus, a step of 12 inches in breadth will require a rise of $5\frac{1}{2}$ inches, which may be taken as a standard, to regulate those of other dimensions.

Though it is desirable to have some criterion as a guide in the arrangement of a design, yet workmen will, of course, vary them as circumstances may require. Stairs are constructed variously, according to the situation and destination of the building.

Geometrical stairs are those which are supported by having one end fixed in the wall, and every step in the ascent having an auxiliary support from that immediately below it, and the lowest step from the floor.

Bracket-stairs are those which have an opening or well, with strings and newels, and are supported by landings and carriages; the brackets are mitred to the ends of each riser, and are fixed to the string-board, which is moulded below like an architrave.

Dog-legged stairs are those which have no opening, or well-hole, and have the rail and balusters of both the progressive and returning flights falling in the same vertical

planes, the steps being fixed to strings, newels, and carriages, and the ends of the steps of the inferior kind terminating only upon the side of the string, without any housing. In taking dimensions and laying down the plan and section of stair-cases, take a rod, and, having ascertained the number of steps, mark the height of the story by standing the rod on the lower floor: divide the rod into as many equal parts as there are to be risers, then, if you have a level surface to work upon below the stair, try each of the risers as you go on, and this will prevent any excess or defect; for any error, however small, when multiplied, becomes of considerable magnitude, and even the difference of an inch in the last riser, will not only have a bad effect to the eye, but will be apt to confuse persons not thinking of any such irregularity. In order to try the steps properly by the story rod, if you have not a level surface to work from, the better way will be, to lay two rods on boards, and level their top surface to that of the floor: place one of these rods a little within the string, and the other near or close to the wall, so as to be at right angles to the starting line of the first riser, or, which is the same thing, parallel to the plan of the string; set off the breadth of the steps upon these rods, and number the risers; you may set not only the breadth of the flyers, but that of the winders also. In order to try the story-rod exactly to its vertical situation, mark the same distances of the risers upon the top edges, as the distances of the plan of string-board, and the rods are from each other.

In bracket-stairs, as the internal angle of the steps is open to the end, and not closed by the string as in common dog-legged stairs, and the neatness of workmanship is as much regarded as in geometrical stairs, the balusters must be neatly dove-tailed into the ends of the steps, two in every step. The face of each front baluster must be in a straight surface with the face of the riser, and, as all the balusters must be equally divided, the face of the middle baluster must stand in the middle of the face of the riser of the preceding step and succeeding one. The risers and heads are all previously blocked and glued together, and when put up, the under side of the step nailed or screwed into the under edge of the riser, and then rough brackets to the rough strings, as in dog-legged stairs, the pitching pieces and rough strings being similar. In glueing up the steps, the best method is to make a templet, so as to fit the external angle of the steps with the nosing.

The steps of geometrical stairs ought to be constructed so as to have a very light and clean appearance when put up: for this purpose, and to aid the principle of strength, the risers and treads, when planed up, ought not to be less than one-eighth of an inch, supposing the going of the stair, or length of the step, to be four feet, and for every six inches in length, another one-eighth may be added. The risers ought to be dove-tailed in the cover, and when the steps are put up, the treads are screwed up from below to the under edge of the risers. The holes for sinking the heads of the screws ought to be bored with a centre-bit, then fitted closely in with wood, well matched, so as entirely to conceal the screws, and appear as one uniform surface. Brackets are mitred to the riser, and the nosings are continued round. In this mode, however, there is an apparent defect; for the brackets, instead of giving support, are themselves unsupported, and dependent on the steps, being of no other use, in point of strength, than merely tying the risers and treads of the internal angles of the steps together: and, from the internal angles being hollow, or a re-entrant angle, except at the ends, which terminate by the wall at one extremity, and by the brackets at the other, there is a want of regular finish. The cavetto, or hollow, is carried round the front of the riser, and is returned at the end, and mitred round the bracket, and if an open string, that is, the under side of the stairs open to view, the hollow is continued along the angle of step and riser.

The best plan, however, of constructing geometrical stairs is, to put up the strings, and to mitre the brackets to the risers, as usual, and enclose the soffit with lath and plaster, which will form an inclined plane under each flight, and a winding surface under the winders. In superior staircases, for the best buildings, the soffit may be divided into panels. If the risers are made from two inch planks, it will greatly add to the solidity. The method of drawing and executing the scroll, and other wreath parts of the hand-rail, will be given in a subsequent part of this article.

In constructing a flight of geometrical stairs, where the soffit is enclosed as above, the bearers should all be framed together, so that when put up, they will form a perfect staircase. Each piece of frame-work, which forms a riser, should, in the partition, be well wedged at the ends. This plan is always advisable when strength and firmness are requisite, as the steps and risers are entirely dependent on the

framed carriages, which, if carefully put together, will never yield to the greatest weight.

Fig. 619 will show the section of this framing firmly put together, and wedged into the partition, as above described.

In preparing the string for the wreath part, a cylinder should be made of the size of the well-hole of the staircase, which can be done at a trifling expense; then set the last tread and riser of the flyers on one side, and the first tread and riser of the returning flight on the opposite side, at their respective heights; then on the centre of the curved surface of this cylinder, mark the middle between the two, and with a thin slip of wood, bent round with the ruling edge, cutting the two nosings of these flyers and passing through the intermediate height marked on the cylinder, draw a line, which will give the wreath line formed by the nosings of the winders; then draw the whole of the winders on this line, by dividing it into as many parts as you want risers, and each point of division is the nosing of such winder. Having thus far proceeded, and carefully examined your heights and widths, so that no error may have occurred, prepare a veneer of the width intended for your string, and the length given by the cylinder, and after laying it in its place on the cylinder, proceed to glue a number of blocks about an inch wide on the back of the veneer, with their fibres parallel to the axis of the cylinder. When dry, this will form the string for the wreath part of the staircase, to be framed into the straight strings. It is here necessary to observe, that about five or six inches of the straight string should be in the same piece as the circular, so that the joints fall about the middle of the first and last flyers. This precaution always avoids a cripple, to which the work would otherwise be subject.

Fig. 618, No. 1, is a plan of a dog-legged staircase, *a* the seats of the newels, *c* the seat of the upper newel.

No. 2. The elevation of the same.

A B. The newels; the part A C being turned.—D E the upper newel.—F G the carriage piece.—H I upper string-board framed into the newel.—K a joist framed into the trimmer.

To describe the ramps; produce the horizontal part of the knee to L, and also the under side of the rail until it meets the face of the first baluster, at *c*, make *c d* equal to *c* D, and upon A *d*, and from the point *d*, draw the perpendicular *d* L, and L is the centre for describing the ramps *d d*.

The story-rod *a b* is a very necessary article in fixing the steps; for, if a common rule be used for this purpose, the workman will be very liable to err and render the stairs extremely faulty, which cannot take place if the story-rod be applied to every riser, and the successive risers be regulated by it.

In the construction of dog-legged staircases, the first thing is, to take the dimensions of the stair, and the height of the story, and lay down a plan and section upon a floor to the full size, representing all the newels and steps; then the situation of the carriages, pitching pieces, long and cross bearers, as also the string-boards; the strings, rails, and newels, being framed together, must be fixed with temporary supports. The string-board will show the situation of the pitching-pieces, which must be put up in order, wedging one end firmly into the wall, and fixing the other to the string-board; this being done, pitch up the rough strings, and finish the carriage part of the flyers. Having proceeded thus far, the steps are next applied, beginning at the bottom and working upwards, the risers being all firmly nailed into the treads.

In the best kind of dog-legged stairs, the nosings are returned; sometimes the risers are mitred to the brackets, and sometimes mitred with quaker strings. In the latter case a hollow is mitred round the internal angle of the under side of the tread and the face of the riser. Sometimes the string is framed into the newel, and notched to receive the ends of the steps; the other end having a corresponding notch-board, and the whole flight being put up like a step-ladder.

Fig. 619, No 1 and 2, is a plan and elevation of a geometrical staircase. The lower part, No. 2, shows the section of the steps and carriages, which are framed together as directed in a former part of this article.

The methods of finding the different moulds necessary in the formation of the wreath part of the hand-rail, will be found in the next plate.

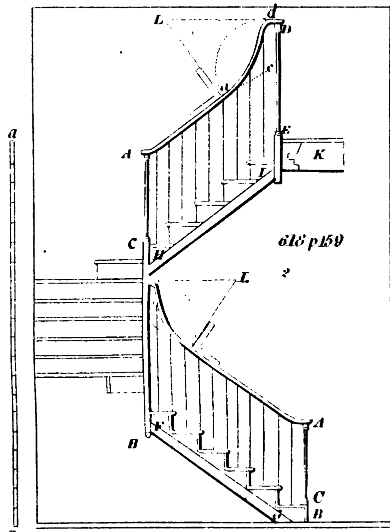
To draw the scroll of a hand-rail.

Fig. 620. First make a circle 3½ inches in diameter, divide the diameter into three equal parts, make a square in the centre of the circle equal to one of those parts and divide each side of the square into six equal parts.

Fig. 4, shows this square on a larger scale, and laid in the same position as the little square above, with the different centres marked. The centre at 1 draws from *a* to *b*, the centre at 2 from *b* to *c*, and the centre at 3 from *c* to *d*, &c. which will complete the outside revolution at A: set the thickness of the rail from *a* and to *x*, draw the inside the reverse way, and the scroll will be completed.

To draw the curtail-steps.

Set the balusters in their proper places on each quarter of the scroll. Fig. 3, the first baluster showing the return of the nosing round the step, the second placed at the beginning of the twist, and the third a quarter distant, and straight with the front of the last riser; then set the projection of the nosing without, and draw it round equally distant from the scroll, which will give the form of the curtail.



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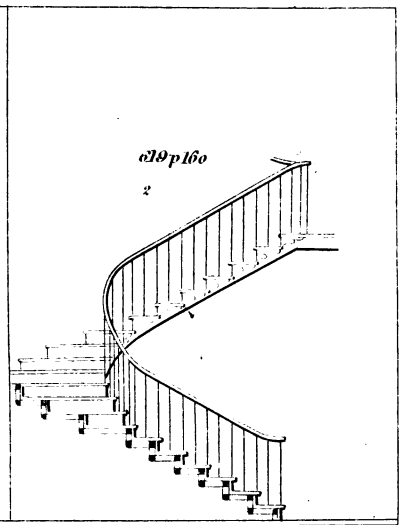

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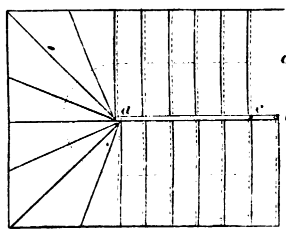

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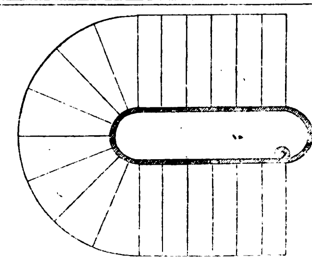

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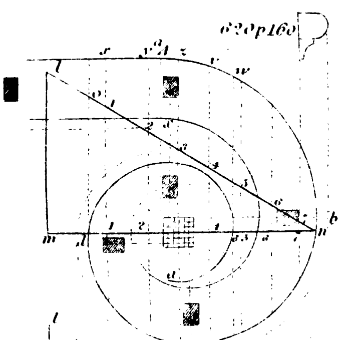

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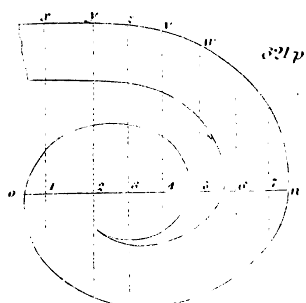

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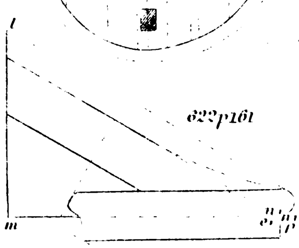

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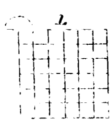

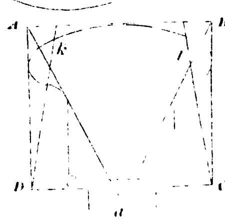

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As the method of getting a scroll out of a solid piece of wood, having the grain of the wood to run in the same direction with the rail, is far preferable to any other method with joints, being much stronger and more beautiful than any other scroll with one or two joints, we shall here give the method of finding a face-mould to apply on the face of the plank.

Place your pitch board *l m n* with *m n* passing through the eye of the scroll, then draw ordinates across the scroll at discretion, and take the length of the line *o n*, with its divisions, and lay it on *o n*, at Fig. 621, then the ordinate being drawn, take the different distances 2 *y*, 3 *z*, 4 *v*, &c. and transfer them to 2 *y*, 3 *x*, 4 *v*, &c. and the rest of the points being taken in the same manner, a curve may be traced which will be the face-mould required.

To find the parallel thickness of the plank.

Fig. 622. Let *l m n* be the pitch board, and let the level of the scroll rise one-sixth, that is, divide *l m* into six equal parts, and the bottom division is the top of the level of the scroll: from the end of the pitch board, set on *n* to *o*, half the thickness of a baluster, to the inside; then set, from *o* to *p*, half the width of the rail, and draw the form of the rail on the end at *p*, the point *n* being where the front of the riser comes, the point *p* will be the projection of the rail before it: draw a dotted line to touch the nose of the scroll, parallel with *l n*, then the distance between this dotted line and the under tip of the scroll, will show the exact thickness of planking; but there is no occasion for the thickness to come quite to the under side, for if it come to the under side of the hollow it will be sufficient, as a little bit glued under the hollow could not be discernible, and can be no hurt to the scroll. In ordinary cases, where the tread is about 11 inches, and rise 6½, a scroll can be got out of a piece, about 4½ inches thick.

To describe a section of a hand-rail, supposing it to be two inches deep, and two and a quarter inches broad, the usual dimensions.

Fig. 622. Let A B C D be a section of a rail, as squared; on A B describe an equilateral triangle A B *a*; from *a*, as a centre, describe an arc to touch A B, and to meet *a* A and *a* B; take the distance between the point of section in *a* A and the point A, and transfer it from the point of section to *k*, upon the same line *a* A, join D *k*; from *k*, with the distance between *k* and the end of the arc, describe another arc, to meet D *k*; with the same distance describe a third arc, of contrary curvature, and draw a vertical line to touch it; which will form one side of the section of the rail, and the counter part may be formed by a similar operation.

The branch of Joinery that falls under our next and last consideration is that of hand-railing; which calls into action all the ingenuity and skill of the workman. This art consists in constructing hand-rails by moulds, according to the geometrical principles, that if a cylinder be cut in any direction, except parallel to the axis, or base, the section will be an ellipsis; if cut parallel to the axis, a rectangle; and if parallel to the base, a circle.

Now, suppose a hollow cylinder be made to the size of the well-hole of the stair-case, the interior concave, and the exterior convex; and the cylinder be cut by any inclined or oblique plane, the section formed will be bounded by two concentric similar ellipses; consequently the section will be at its greatest breadth at each extremity of the larger axis, and its least breadth at each extremity of the smaller axis. Therefore, in any quarter of the ellipsis there will be a continued increase of breadth from the extremity of the lesser axis to that of the greater. Now it is evident that a cylinder can be cut by a plane through any three points; therefore, supposing we have the height of the rail at any three points in the cylinder, and that we cut the cylinder through these points, the section will be a figure equal and similar to the face-mould of the rail; and if the cylinder be cut by another plane parallel to the section, at such a distance from it as to contain the thickness of the rail, this portion of the cylinder will represent a part of the rail with its vertical surfaces already worked: and, again, if the back and lower surface of this cylindric portion be squared to vertical lines, either on the convex or concave side, through two certain parallel lines drawn by a thin piece of wood which is bent on that side, the portion of the cylinder thus formed, will represent the part of the rail intended to be made.

Though the foregoing only relates to cylindrical well-holes, it is equally applicable to rails erected on any seat whatever.

The *face-mould* applies to the two faces of the plank, and is regulated by a line drawn on its edge, which line is vertical when the plank is elevated to its intended position. This is also called the *raking-mould.*

The *falling-mould* is a parallel piece of thin wood applied and bent to the side of the rail-piece, for the purpose of drawing the back and lower surface, which should be so formed, that every level straight line, directed to the axis of the well-hole, from every point of the side of the rail formed by the edges of the falling mould, coincide with the surface.

In order to cut the portion of rail required, out of the least possible thickness of stuff, the plank is so turned up on one of its angles, that the upper surface is no where at right angles to a vertical plane passing through the chord of the plane; the plank in this position is said to be *sprung.*

The *pitch-board*, is a right-angled triangular board made to the rise and tread of the step, one side forming the right

angle of the width of the tread, and the other of the height of the riser. When there are both winders and flyers; two pitch boards must be made to their respective treads, but, of course, of the same height, as all the steps rise the same.

The bevel by which the edge of the plank is reduced from the right angle when the plank is sprung, is termed the *spring of the plank*, and the edge thus bevelled is called the *sprung edge.*

The bevel by which the face-mould is regulated to each side of the plank, is called the *pitch.*

The formation of the upper and lower surfaces of a rail is called the *falling of the rail;* the upper surface of the rail is termed the *back.*

In the construction of hand-rails, it is necessary to spring the plank, and then to cut away the superfluous wood, as directed by the draughts, formed by the face-mold; whichu may be done by an experienced workman, so exactly, with a saw, as to require no further reduction; and when set in its place, the surface on both sides will be vertical in all parts, and in a surface perpendicular to the plan. In order to form the back and lower surface, the falling mould is applied to one side, generally the convex, in such a manner, that the upper edge of the falling mould at one end, coincides with the face of the plank; and the same in the middle, and leaves so much wood to be taken away at the other end as will not reduce the plank on the concave side;—the piece of wood to be thus formed into the wreath or twist being agreeable to their given heights.

In the following figures, we have given the method of finding the moulds necessary for constructing a hand-rail on a circular plan.

Fig. 623, is the plan, showing part of the winders, which in this case are eight, as also the seat of the joint.

Fig. 624. Let A A A, &c. be the outside, and *a a a*, &c. the inside of the plan. B C D a line passing through the middle of the breadth, B C being straight, and C D one-fourth of the circumference of the circle, the point E in the middle of the arc C D, B at one extremity of the line B C E D, and D at the other.

Divide the quadrant C D into any number of equal parts, which in this example are four. Draw the straight line M N, fig. 625, and make M N equal to the development of the quadrant A A A, &c. on the convex side. Draw M O perpendicular to M N, and make M O equal to the height of a step; draw O P parallel to M N, and make O P equal in length to the width of a step, and join P M.

Draw N *s* perpendicular to M N. In N *s* make N *o* equal to the height of four of the winders, and join *o* M; curve off the angle at M, in the manner shown below, by intersection of lines. Through *o* draw *x y* perpendicular to M *o*, make *o x* and *o y* each equal to half the width of the falling mould, and draw the upper and lower edges of the mould.

Join D E, fig. 624, and produce D E to F. Draw D G and E L. Make D G equal to one-fourth, (or any part of,) the height from N to the upper edge of the falling mould, Fig. 625, and E L equal to one-fourth, or the same part, of the height from Q to the upper edge of the falling mould. Join G L and produce it to meet D E in F, join the dotted line B F. Draw I K, through the centre F, perpendicular to B F. Draw *a b*, *a b*, &c. meeting I K. At any convenient distance from K I draw *c d* parallel to I K. Make the perpendicular of the face-mould equal to its corresponding height on the falling-mould, and draw the straight line *c e*; then draw ordinates A *b*, A *b*, &c. continue them until they meet *c e*, and from the points of intersection draw perpendiculars to *c e*, and set off the distances as shown by corresponding letters. Then by tracing a curve through these points, the face-mould will be completed.

The top line *r r r*, &c. fig. 625, is left on the falling-mould, to regulate its position when bent upon the convex surface, as the line *r r r*, and will fall into the plane surface of the top of the plank. This line is obtained by making the perpendiculars *f r*, 2 *r*, *f r*, &c. equal to the corresponding perpendiculars *f b*, *f b*, &c. Fig. 624. To find the face-mould of a staircase. so that when set to its proper rake it will be perpendicular to the plan whereon it stands for a level landing.

Fig. 626. Draw the central line, *a b*, parallel to the sides of the rail, on the right line *a b* apply the pitch-board of a flyer, from *b* to *c* draw ordinates *n m*, *o p*, *q r*, *s t*, *u v*, at discretion, observing to draw one from the point *r*, so that you may obtain the same point exactly in the face-mould; then take the parts which the ordinates give on the line *a b*, and apply them at Fig. 627, and take the distances *m n*, *p o*, &c. and transfer them so Fig. 627, and a curve through these points will be the face mould required.

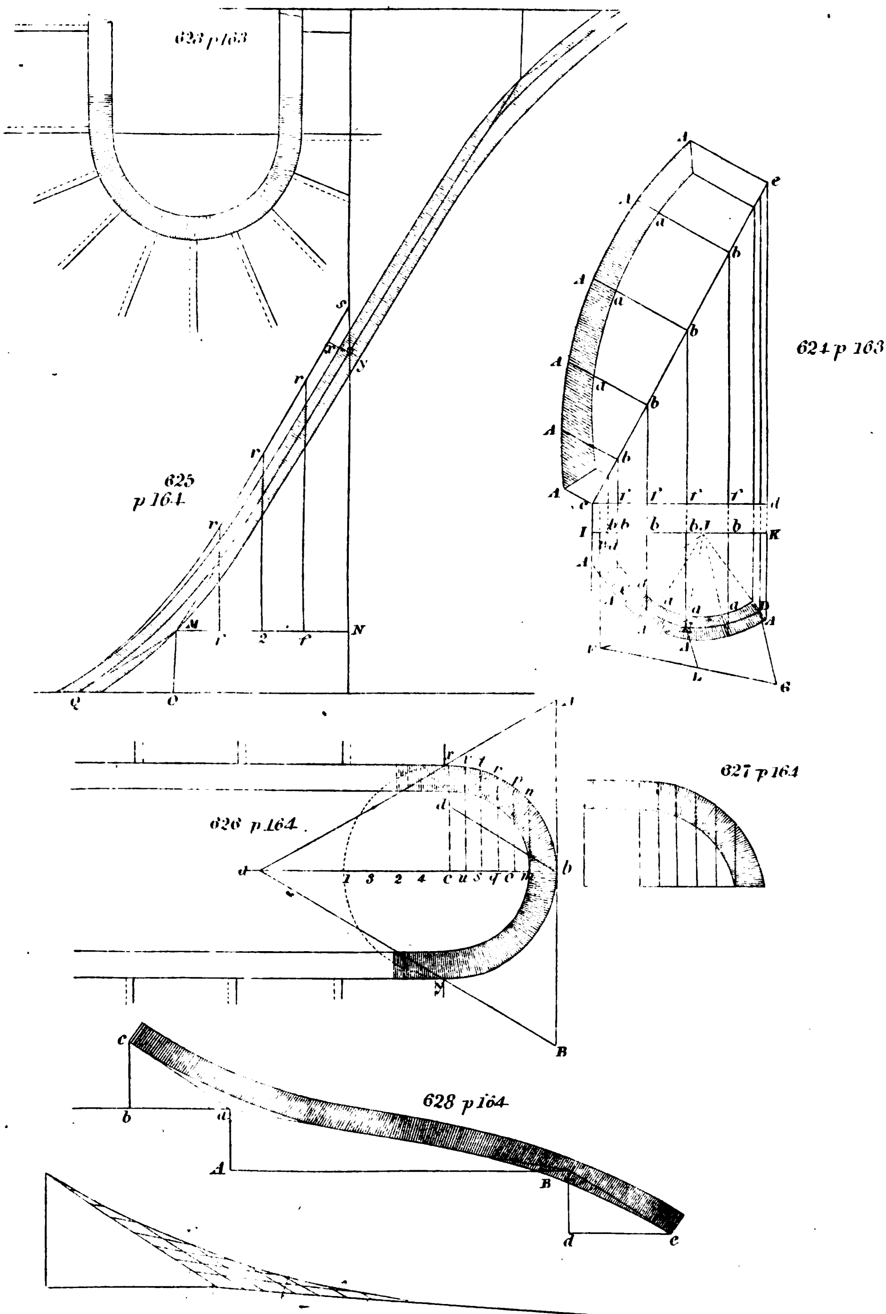
To find the falling mould.

Fig. 626. Divide the radius of the circle into four equal parts, and set three of these parts from 4 to *a*; through *x y*, the extremities of the diameter of the rail, draw *a x* and *a y*, producing them till they touch the tangent A B; then will A B be the circumference of the semicircle *x b y*, which is applied from A to B, Fig. 628, as a base line. Make A *a* the height of a step; draw the hypotenuse *a* B, apply the pitch board of a flyer at *a b c*, and B *d e*, then curve off the angle by intersection of lines, and draw a line parallel to it for the upper edge of the mould.

MEASURES CUSTOMARY IN JOINER'S WORK.

Prepared boarding is measured by the foot superficial; the following being the different distinctions:—edges shot; edge shot, ploughed and tongued; wrought on one side, and edges shot; wrought on both sides, and edges shot; wrought on both sides, ploughed, and tongued; boards keyed and clamped, mortise-clamped, and mortise and mitre-clamped. The prices are regulated according to the thickness. If the boards be glued, an additional price per foot is allowed; if tongued, still more, according to the description of tongue. In boarded flooring, the dimensions are taken to the extreme parts, from which the squares are to be computed. Deductions for chimneys, stair-cases,

From 623 to 628



&c. are taken from this. The price depends on the surface, whether wrought or plain, the manner of the longitudinal and heading-joints, the thickness of stuff, whether the boards be laid one after the other, or folded, or whether the floor be laid with boards, battens, or wainscot.

Skirting, when wide, is also measured by the foot superficial; the price depending upon the position, whether level, raking, or ramping, or upon the manner of finishing, whether plain, torus, or rebated, or scribed to the floor, or to the steps, or upon the plan, whether straight or circular.

Weather-boarding is measured by the square of 100 superficial feet.

Boarded partitions are measured by the square, from which must be deducted the doors and windows, except an agreement be made to the contrary.

The price of all kinds of framing depends on the thickness, or whether the framing be plain or moulded; and if moulded, the description of moulding, whether struck on the solid, or laid in, mitred, or scribed; as also upon the number of panels in a given height and breadth, and upon the nature of the plan.

The different kinds of wainscotting, as window linings, door linings, back linings, partitions, doors, shutters, &c. are all measured by the superficial foot.

Windows are in general valued by the foot superficial; though sometimes by the window. When measured, the dimensions are taken for height, from the top of the cill to the under side of the head, allowing seven inches for the head and cill; and for width in clear of pulley-stiles, allowing eight inches. The sash and frame are either measured together or separately.

Skylights are measured by the foot superficial, their price depending on the plan and elevation. Framed grounds at per foot run.

Ledged doors by the foot superficial, dado by the superficial foot; the price depending whether the plan be straight or circular, or the elevation level or inclined.

In measuring stair-cases, the risers, treads, and carriages, are generally classed together, and measured by the foot superficial: the price varying as the steps are flyers or winders, as the risers are mitred into the string-board, the treads dove-tailed for balusters, and the nosings returned, or whether the bottom of the risers be tongued into the treads. The curtail step is generally valued as a whole. Returned nosings at so much each; and if circular, double the price of straight ones.

The brackets at so much each, according to the pattern, and whether straight or circular.

Hand-railing is measured by the foot run, the price depending on the materials, the diameter of the well-hole, or whether ramped, swan-necked, level, circular, or wreathed, or whether made out of the solid, or in thicknesses. The scroll is paid at per piece. The joints at so much each, and three inches of the straight part at each end of the wreath are included in the measurement. Deal balusters are prepared and fixed at per piece; as also iron balusters, iron column to curtail, housings to steps, &c. An extra allowance is made for the additional labour in fixing the iron balusters.

The price of string-board is regulated by the foot superficial, according to the manner in which it is moulded, whether straight, circular, or wreathed, and the manner in which such string is backed. The shafts of columns are measured by the foot superficial; the price depending upon the diameter, and whether it be straight or curved, or properly glued and blocked. If the column be fluted or reeded, the flutes or reeds are measured by the foot run, their price depending upon the size of the flute or reed. The headings of flutes and reeds are at so much each. Pilasters, straight or curved, in the height, are measured in the same way, and the price taken per foot superficial in the caps and bases if pilasters; besides the mouldings, the mitres must be so much each, according to the size.

Mouldings are valued by the foot run, as double-faced architraves, base and surbase. The head of an architrave in a circular wall, is four times the price of the perpendicular parts, not only on account of the time required to form the mouldings to the circular plan, but on account of the greater difficulty of forming the mitres.

All horizontal mouldings, circular upon plan, are three or four times the price of those on a straight plan; being charged more, as the radius of the circle is less: housings to mouldings are valued at so much each, according to the size.

The price per superficial foot of moulding is regulated by the number of quirks, for each of which an addition is made to the foot.

The price of mouldings depends also upon the materials of which they are made, and upon their running figure, whether curved or raking.

In grooving, the stops are paid over and above, and so much more must be allowed for all grooves wrought by hand, particularly in the parts adjoining the concourse of

an angle: circular grooving must be paid still more. Water trunks are measured by the foot run; the rate depending upon the side of their square: the hopper-heads and shoes are valued at so much each, as also are the moulded weather caps, and the joints. Scaffolding, &c. used in fixing, is charged extra.

Flooring-boards are prepared, that is, planed, gauged, and rebated to a thickness at so much each, the price depending upon the length of each board; if more than nine inches broad, the rate is increased according to the additional width; each board listing at so much per list.

The following is a classification of such articles in joinery as are usually rated at so much each.

Trusses.
Cantalivers.
Rule-joints.
Cut brackets for shelves.
Housings in general.
Housings to steps.
Cuttings to standards.
Elbow cappings.
Returned moulded nosings to steps.
Caps to hand-rails.
Scroll of hand-rails.
Making and fixing joints of hand-rails with joint-screws.
Fixing iron columns in curtails.
Fixing iron baluster, and preparing mould.
Preparing and fixing deal balusters.
Brackets to stairs.
Curtail step.
Clamp-mitres.
Mitres of pilasters according to their size.
Mitres of cornices.
Headings to flutes and reeds.
Hopper-heads and shoes to water-trunks.
Joints to water-trunks.
Preparing flooring-boards and battens.
Fixing locks and fastenings, per article.
Hole in seat of water-closet.
Patteras.

Articles at per foot running, or lineal.

Sinking to shelves.
Moulded raisings of panels.
All raised panels in the extremity of the raising to be charged extra.
Capping to wainscot.
Level circular string-boards to stairs.
Hand-rails
Newels to stairs.
Moulded planiers in stairs.
Sinking in rail for iron rail or balusters.
Water-trunks and spouts.
Skirting and door-grounds.
Beads or fillets.
Fillets mitred on panels.
Square or beaded angle-staff rebated.
Mouldings.
Single cornice.
Single-faced architrave.
Pilasters under four inches wide.
Boxings to windows.
Ornamental grooving.
Narrow linings.
Legs, rails, and runners of dressers.
Border to hearth.
Base-moulding.
Surbase-moulding.
Narrow skirting.

Articles at per foot superficial.

Deals planed, ploughed, tongued, beaded, glued, and clamped.
Skirting.
Sash-frames and sashes.

Skylights.
Back, elbow, soffits.
Shutters.
Framed or plain back-linings.
Door-linings, jambs.
Wainscotting.
Dado.
Partitions.
Steps and rises to stairs, including carriages.
Cradling.
Double-faced architraves.
Mouldings wrought by hand, if large.
Shafts and columns.

PLASTERING.

The Plasterer is a workman to whom the decorative part of architecture owes a considerable portion of its effect, and whose art is requisite in every kind of building.

The tools of the plasterer consists of a *spade* or shovel of the usual description; a *rake*, with two or three prongs, bent downwards from the line of the handle, for mixing the hair and mortar together; *trowels* of various kinds and sizes; stopping and picking-out tools; rules called *straight-edges;* and wood *models*.

The trowels used by plasterers are more neatly made than tools of the same name used by other artificers. The *laying and smoothing tool* consists of a flat piece of hardened iron, about ten inches in length, and two inches and a half wide, very thin, and ground to a semicircular shape at one end, but left square at the other; and at the back of the plate, near the square end, is rivetted a small iron rod with two legs, one of which is fixed to the plate, and the other to a round wooden handle. With this tool all the first coats of plaster is laid on, as are also the last, or, as it is technically termed, the *setting*. The other kinds of trowels are made of three or four sizes, for *gauging* the fine stuff and plaster, used in forming cornices, mouldings, &c. The longest size of these is about seven inches on the plate, which is of polished steel, about two inches and three-quarters broad at the heel, diverging gradually to a point. To the heel or broad end a handle is adapted.

The *stopping and picking-out tools* are made of polished steel, of different sizes, though most generally about seven or eight inches in length, and half an inch in breadth, flattened at both ends, and ground somewhat round. These tools are used in modelling and finishing mitres and returns to cornices; as likewise in filling-up and perfecting the ornaments at the joinings.

The *straight edges* are for keeping the work in an even, or perpendicular line; and the *models* or *moulds* are for run-

ning plain mouldings, cornices, &c.; of these latter the plasterer requires a great number, as very little of his finishing can be done without them.

Experienced workmen keep their tools very clean, and have them daily polished by the hawk-boys.

Plasterers have technical divisions of their work, by which its quality is designated, and value ascertained; as, lathing; laying; pricking-up; lathing, laying, and set; lathing, floating, and set; screed, set or putty; rendering and set, or rendering, floated, and set; trowelled stucco, &c.; each of which, hereafter, we shall very minutely explain.

In all the operations of plastering, lime extensively abounds; we shall, therefore, first offer some observations on the properties of this important article.

All who have written on the subject of lime, as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement; but with a little attention it is evident, that all prescribed rules must be so very vague and uncertain, as to be of little utility to the workman, for, besides the variation which is occasioned by a more or less degree of calcination, it is a certain fact, that some kinds of lime-stone are much more pure, and contain a much smaller proportion of sand than others; consequently, it would be absurd to say, that pure lime requires as small a proportion of sand, when made into mortar, as that which originally contained in itself a large proportion.

The variation thus produced, in regard to the proportion of sand, is found to be extremely great. It is, however, stated, that the best mortar which has come under examination, was formed of eleven parts of sand to one of lime: to which was added, by measure, between twice and thrice its own bulk of sand, which may be allowed to have been at least three times its quantity by weight. Supposing, therefore, that every particle of the lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime; but it is hard to suppose, that above one hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

From these considerations it is conceived, that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime, and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would

seem, that it might be safely inferred, that the moderns in general rather err in giving too little, than in giving too much sand. It deserves, however, to be noticed, that the sand, when naturally in the lime-stone, is more intimately blended with the lime, than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make equally good mortar artificially from pure lime, with so small a proportion of caustic calcareous matter, as may sometimes be effected when the lime naturally contains a very large proportion of sand. Still, however, there seems to be no doubt, that if a much larger proportion of sand than is common were employed, and that more carefully and expeditiously blended and worked, the mortar would be made much more perfect, as has been proved by actual experiments.

Another circumstance, which greatly tends to vary the quality of cement, and to make a greater or smaller proportion of sand necessary, is, the mode of preparing the lime before it is beaten up into mortar. When for plaster, it is of great importance to have every particle of the lime-stone slaked before worked-up, for, as smoothness of surface is the most material point, if any particles of lime be beaten-up before sufficiently slaked, the water still continuing to act on them, will cause them to expand, which will produce those excrescences on the surface of the plaster, termed blisters. Consequently, in order to obtain a perfect kind of plaster, it is absolutely necessary that the lime, before being worked, be allowed to remain a considerable time macerating or *souring* in water: the same sort of process, though not absolutely required, would considerably improve the lime intended for mortar. Great care is required in the management; the principal thing being the procuring of well-burnt lime, and allowing no more lime, before worked, than is just sufficient to macerate or *sour* it with the water: the best burnt lime will require the maceration of some days.

It has been almost universally admitted, that the hardest lime-stone affords the lime which will consolidate into the firmest cement; hence, it is generally concluded, that lime made of chalk produces a much weaker cement than that made of marble, or lime-stone. It would seem, however, that, if ever this be the case, it is only incidentally, and not necessarily. In the making of mortar, other substances are occasionally mixed with lime, which we shall here proceed to notice, and endeavour to point out their excellencies and

defects. Those commonly used, besides sand of various denominations, are powdered sand-stone, brick-dust, and sea-shells: and for forming plaster, where closeness rather than hardness is required, lime which has been slaked and kept in a dry place till it has become nearly effete, and powdered chalk, or whiting, and gypsum, in various proportions, besides hair and other materials of a similar nature. Other ingredients have been more lately recommended, such as earthy balls, slightly burnt and pounded, old mortar rubbish, powdered and sifted, and various things of the like kind, the whole of which are, in some respect or other, objectionable.

Plaster of Paris is employed by the plasterer to give the requisite form and finish to all the superior parts of his work.

It is made of a fossile stone, called gypsum, which is excavated in several parts of the neighbourhood of Paris, whence it derives its name, and is calcined to a powder, to deprive it of its water of crystallization. The best is Montmartre.

The stones are burnt in kilns, which are generally of very simple construction, being not unfrequently built of the gypsum itself. The pieces to be calcined are loosely put together in a parallelopiped heap, below which are vaulted pipes or flues, for the application of a moderate heat.

The calcination must not be carried to excess; as otherwise the plaster will not form a solid mass when mixed with a certain portion of water. During the process of calcination, the water of crystallization rises as white vapour, which if the atmosphere be dry, is quickly dissolved in air.

The pounding of the calcined fragments is performed sometimes in mills constructed for the purpose, and sometimes by men, whose health is much impaired by the particles of dust settling upon their lungs.

On the river Wolga, in Russia, where the burning of gypsum constitutes one of the chief occupations of the peasantry, all kinds of gypsum are burnt promiscuously on grates made of wood; afterwards the plaster is reduced to powder, passed through a sieve, and finally formed into small round cakes, which are sold at so much per thousand.

These balls are reduced into an impalpable powder by the plasterer, and then mixed with mortar. The less the gypsum is mixed with other substances, the better it is qualified for the purpose of making casts, stucco, &c. The sparry gypsum, or selenite, which is the purer kind, is employed for taking impressions from coins and medals, and for making those beau-

tiful imitations of marble, granite, and porphyry, known by the name of *scagliola*, which is derived from the Italian word *scagli*.

Finely powdered alabaster, or plaster of Paris, when heated in a crucible, assumes the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c. all of which properties it again loses on the departure of the heat: if taken from the crucible and thrown upon paper, it will not wet it; but immediately be as motionless as it was before exposed to the heat.

Two or three spoonfuls of burnt alabaster mixed up thin with water, will, at the bottom of a vessel filled with water, coagulate into a hard lump, notwithstanding the water that surrounds it. The coagulating or setting property of burnt alabaster will be very much impaired, or lost, if the powder be kept for any considerable time, and more especially in the open air. When it has been once tempered with water, and suffered to grow hard, it cannot be rendered of any further use.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets, or grows firm, and at the instant of its setting, has its bulk increased. This expansive property, in passing from a soft to a firm state, is one of its valuable properties; rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts. It is also probable that this expansion of the plaster might be made to contribute to the elegance of the impressions it receives from medals, &c. by properly confining it when soft, so that, at its expansion, it would be forced into the minutest traces of the figures.

A plaster of a coarser description, made of a bluish stone, much like that of which Dutch terras are made, is sometimes used in this country, for floors in gentlemen's houses, and for corn-granaries. This stone, when burnt after the manner of lime, assumes a white appearance, but does not ferment on being mixed with water: when cold, it is reduced to a fine powder. About a bushel of this powder is put into a tub, and water is applied till it becomes liquid. In this state it is well stirred with a stick, and used immediately; for in less than a quarter of an hour it becomes hard and useless, as it will not allow of being mixed a second time.

Other cements are used by plasterers for inside work. The first is called *lime and hair*, or *coarse stuff*, and is pre-

pared as common mortar, with the addition of hair from the tan-yards. The mortar is first mixed with a requisite quantity of sand, and the hair is afterwards worked in by the application of a rake.

Next to this is *fine stuff*, which is merely pure lime, slaked first with a small quantity of water, and afterwards, without any extraneous addition, supersaturated with water, and put into a tub in a half fluid state, where it is allowed to remain till the water is evaporated. In some particular cases, a small portion of hair is incorporated. When this fine stuff is used for inside walls, it is mixed with very fine washed sand, in the proportion of one part sand to three parts of fine stuff, and is then called *trowelled* or *bastard stucco*, with which all walls intended to be painted are finished.

The cement called *guage stuff*, consists of three-fifths of fine-stuff, and one-fifth plaster of Paris, mixed together with water, in small quantities at a time, to render it more ready to set. This composition is mostly used in forming cornices and mouldings run with a wooden mould. When great expedition is required, plasterers guage all their mortars with plaster of Paris, which sets immediately.

The technical divisions of plasterer's work shall now claim our attention.

Lathing, the first operation, consists in nailing laths on the ceiling, or partition. If the laths be of oak, they will require wrought iron nails; but if of deal, nails made of cast iron may be used. Those mostly used in London are of fir, imported from America and the Baltic, in pieces called staves. Laths are made in three foot and four foot lengths: and with respect to their thickness and strength, are either single, lath and half, or double. The single are the thinnest and cheapest; those called *lath and half*, are supposed to be one-third thicker than the single; and the double laths are twice that thickness. In lathing ceilings, the plasterer should use both the lengths alluded to, and in nailing them up, should so dispose them that the joints be as much broken as possible, that they may have the stronger key or tie, and thereby strengthen the plastering with which they are to be covered. The thinnest laths are used in partitions, and the strongest for ceilings.

Laths are also distinguished into heart and sap laths: the former should always be used in plain tiling; the latter, which are of inferior quality, are most frequently used by the plasterer.

Laths should be as evenly split as possible. Those that are very crooked should not be used, or the crooked part should be cut out; and such as have a short concavity on the one side, and a convexity on the other, not very prominent, should be placed with the concave sides outwards.

The following is the method of rendering or splitting laths. The lath-cleavers having cut their timber into the required lengths, cleave each piece with wedges, into eight, twelve, or sixteen pieces, according to the scantling of the timber, called *bolts;* and then, with dowl-axes, in the direction of the felt-grain, termed *felting*, into sizes for the breadth of the laths; and, lastly, with the *chit*, clear them into thicknesses by the *quarter grain.*

Having nailed the laths in their appropriate order, the plasterer's next business is to cover them with plaster, the most simple and common operation of which, is *laying;* that is, spreading a single coat of lime and hair over the whole ceiling, or partition; carefully observing to keep it smooth and even in every direction. This is the cheapest kind of plastering.

Pricking-up is performed in the same manner as the foregoing, but is only a preliminary to a more perfect kind of work. After the plaster is laid on, it is crossed all over with the end of a lath, to give it a tie or key to the coat, which is afterwards to be laid upon it.

Lathing, laying, and set, or what is termed *lath and plaster, one coat and set*, is, when the work, after being lathed, is covered with one coat of lime and hair, and afterwards, when sufficiently dry, a thin and smooth coat spread over it, consisting of lime only, or, as the workmen call it, *putty*, or *set.* This coat is spread with a smoothing-trowel, used by the workman with his right hand, while his left hand moves a large flat brush of hog's bristles, dipped in water, backwards and forwards over it, and thus produces a surface tolerably even for cheap work.

Lathing, floating, and set, or *lath and plaster, one coat, floated and set*, differs from the foregoing in having the first coat pricked up to receive the set, which is here called the *floating*. In doing this, the plasterer is provided with a substantial straight-edge, frequently from ten to twelve feet in length, which must be used by two workmen. All the parts to be floated are tried by a plumb-line, to ascertain whether they be perfectly flat and level, and whenever any deficiency appears, the hollow is filled up with a trowel full or more of lime and hair only, which is termed *filling-out*,

and when these preliminaries are settled, the *screeds* are next formed. The term *screed* signifies a style of lime and hair, about seven or eight inches in width, gauged quite true, by drawing the straight-edge over it until it be so. These screeds are made at the distance of about three or four feet from each other, in a vertical direction, all round the partitions and walls of a room. When all are formed, the intervals are filled up with lime and hair, called by the workmen, *stuff*, till flush with the face of the screeds. The straight-edge is then worked horizontally on the screeds, by which all the superfluous stuff, projecting beyond them in the intervals is removed, and a plain surface produced. This operation is termed *floating*, and may be applied to ceilings as well as to partitions, or upright walls, by first forming the screeds in the direction of the breadth of the apartment, and filling up the intervals as above described. As great care is requisite to render the plaster sound and even, none but skilful workmen should be employed.

The *set* to floated-work is performed in a mode similar to that already prescribed for *laying;* but being employed only for best rooms, is done with more care. About one-sixth of plaster of Paris is added to it, to make it set more expeditiously, to give it a closer and more compact appearance, and to render it more firm and better calculated to receive the white-wash or colour when dry. For floated stucco-work the pricking-up coat cannot be too dry; but, if the floating which is to receive the setting coat be too dry, before the set is laid on, there will be danger of its peeling off or of assuming the appearance of little cracks, or shells, which would disfigure the work. Particular care and attention therefore must be paid to have the under coats in a proper state of dryness. It may here be observed, that cracks, and other unpleasant appearances in ceilings, are more frequently the effect of weak laths being covered with too much plaster, or too little plaster upon strong laths, rather than of any sagging or other inadequacy in the timbers, or the building. If the laths be properly attended to, and the plaster laid on by a careful and judicious workman, no cracks or other blemishes are likely to appear.

The next operation combines both the foregoing processes, but requires no lathing; it is called *rendering and set*, or *rendering, floated, and set*. What is understood by *rendering*, is the covering of a brick or stone wall with a coat of lime and hair, and by *set* is denoted a superficial coat of fine stuff or putty upon the rendering. These ope-

rations are similar to those described for setting of ceilings and partitions; and the *floated and set* is laid on the rendering in the same manner as on the partitions, &c. already explained, for the best kind of work.

Trowelled stucco, which is a very neat kind of work, used in dining-rooms, halls, &c. where the walls are prepared to be painted, must be worked upon a floated ground, and the floating be quite dry before the stucco is applied. In this process the plasterer is provided with a wooden tool, called *a float*, consisting of a piece of half-inch deal, about nine inches long and three wide, planed smooth, with its lower edges a little rounded off, and having a handle on the upper surface. The stucco is prepared as above described, and afterwards well beaten and tempered with clear water. The ground intended to be stuccoed is first prepared with the large trowel, and is made as smooth and level as possible; when the stucco has been spread upon it to the extent of four or five feet square, the workman, with a float in his right hand and a brush in his left, sprinkles with water, and rubs alternately the face of the stucco, till the whole is reduced to a fine even surface. He then prepares another square of the ground, and proceeds as before, till the whole is completed. The water has the effect of hardening the face of the stucco. When the floating is well performed, it will feel as smooth as glass.

Rough casting, or rough walling, is an exterior finishing, much cheaper than stucco, and, therefore, more frequently employed on cottages, farm-houses, &c. than on buildings of a higher class. The wall intended to be rough-cast, is first pricked-up with a coat of lime and hair; and when this is tolerably dry, a second coat is laid on, of the same materials as the first, as smooth as it can possibly be spread. As fast as the workman finishes this surface, he is followed by another with a pail-full of rough-cast, with which he bespatters the new plastering, and the whole dries together. The rough-cast is composed of fine gravel, washed from all earthy particles, and mixed with pure lime and water till the whole is of a semi-fluid consistency. This is thrown from the pail upon the wall with a wooden float, about five or six inches long, and as many wide, made of half-inch deal, and fitted with a round deal handle. While, with this tool, the plasterer throws on the rough-cast with his right hand, he holds in his left a common whitewashers' brush, dipped in the rough-cast also, with which he brushes and colours the mortar and the rough-cast he has already spread,

to give them, when finished, a regular uniform colour and appearance.

Cornices are either plain or ornamented, and sometimes embrace a portion of both classes. The first point to be attended to is, to examine the drawings, and measure the projections of the principle members, which, if projecting more than seven or eight inches, must be bracketed. This consists in fixing up pieces of wood, at the distance of about ten or twelve inches from each other, all round the place proposed for the cornice, and nailing laths to them, covering the whole with a coat of plaster. In the brackets, the stuff necessary to form the cornices must be allowed, which in general is about one inch and a quarter. A beech mould is next made by the carpenter, of the profile of the intended cornice, about a quarter of an inch in thickness, with the quirks, or small sinkings, of brass or copper. All the sharp edges are carefully removed by the plasterer, who opens with his knife all the points which he finds incompetent to receive the plaster freely.

These preliminaries being adjusted, two workmen, provided with a tub of putty and a quantity of plaster of Paris, proceed to run the cornice. Before using the mould, they gauge a screed of putty and plaster upon the wall and ceiling, covering so much of each as will correspond with the top and bottom of the intended cornice. On this screed one or two slight deal straight-edges, adapted to as many notches or chases made in the mould for it to work upon, are nailed. The putty is then mixed with about one-third of plaster of Paris, and brought to a semi-fluid state by the addition of clean water. One of the workmen, with two or three trowels-full of this composition upon his *hawk*, which he holds in his left hand, begins to plaster over the surface intended for the cornice, with his trowel, while his partner applies the mould to ascertain when more or less is wanted. When a sufficient quantity of plaster is laid on, the workman holds his mould firmly against both the ceiling and the wall, and moves it backwards and forwards, which removes the superfluous stuff, and leaves an exact impression of the mould upon the plaster. This is not effected at once; for while he works the mould backwards and forwards, the other workman takes notice of any deficiencies, and fills them up by adding fresh supplies of plaster. In this manner a cornice from ten to twelve feet in length may be formed in a very short time; indeed, expedition is essentially requisite, as the plaster of Paris occasions a very great tendency in the

putty to set, to prevent which it is necessary to sprinkle the composition frequently with water, as plasterers, in order to secure the truth and correctness of the cornice, generally endeavour to finish all the lengths, or pieces, between any two breaks or projections, at one time. In cornices which have very large proportions, and in cases where any of the orders of architecture are to be introduced, three or four moulds are required, and are similarly applied, till all the parts are formed. Internal and external mitres, and small returns, or breaks, are afterwards modelled and filled up by hand.

Cornices to be enriched with ornaments, have certain indentations, or sinkings, left in the mould in which the casts are laid. These ornaments were formerly made by hand; but now are cast in plaster of Paris, from clay models. When the clay model is finished, and has, by exposure to the action of the atmosphere, acquired some degree of firmness, it is let into a wooden frame, and when it has been retouched and finished, the frame is filled with melted wax, which when cold is, by turning the frame upside down, allowed to fall off, being an exact cameo, or counterpart, of the model. By these means, the most enriched and curiously wrought mouldings may be cast by the common plasterer. These wax models are contrived to cast about a foot in length of the ornament at once; such lengths being most easily got out from the cameo. The casts are made of the finest and purest plaster of Paris, saturated with water; and the wax mould is oiled previously to its being put in. When the casts, or intaglios, are first taken from the mould, they are not very firm; but being suffered to dry a little, either in the open air or an oven, they acquire sufficient hardness to allow of being scraped and cleaned.

Basso-relievos and friezes are executed in a similar manner, only the wax mould is so made, that the cast can have a back-ground at least half an inch thick of plaster-cast to the ornament or figure, in order to strengthen and secure the proportions, at the same time that it promotes the general effect.

The process for capitals to columns is also the same, except that numerous moulds are required to complete them. In the Corinthian capital a shaft or belt is first made, on which is afterwards fixed the foliage and volutes; the whole of which require distinct cameos.

In running cornices which are to be enriched, the plasterer takes care to have proper projections in the running-

mould, so as to make a groove in the cornice, for the reception of the cast ornament, which is laid in and secured by spreading a small quantity of liquid plaster of Paris on its back. Detached ornaments intended for ceilings or other parts, and where no running mould has been employed, are cast in pieces corresponding with the design, and fixed upon the ceiling, &c. with white-lead, or with the composition known by the name of *iron-cement*.

The manufacture of stucco has, for a long time past, attracted the attention of all connected with this branch of building, as well as chemists and other individuals; but the only benefit resulting from such investigation is, a more extensive knowledge of the materials used. It would seem, that the great moisture of our climate prevents its being brought to any high degree of perfection; though, among the various compositions which have been tried and proposed, some, comparatively speaking, are excellent.

Common stucco, used for external work, consists of clean washed Thames sand and ground Dorking lime, which are mixed dry, in the proportion of three of the latter to one of the former: when well incorporated together, these should be secured from the air in casks till required for use. Walls to be covered with this composition, must first be prepared, by raking the mortar from the joints, and picking the bricks or stones, till the whole is indented: the dust and other extraneous matter must then be brushed off, and the wall well saturated with clean water. The stucco is supersaturated with water, till it has the appearance and consistence of ordinary white-wash, in which state it is rubbed over the wall with a flat brush of hogs' bristles. When this process, called *roughing in*, has been performed, and the work has become tolerably dry and hard, which may be known by its being more white and transparent, the screeds are to be formed upon the wall with fresh stucco from the cask, tempered with water to a proper consistency, and spread on the upper part of the wall, about eight or nine inches wide; as also against the two ends, beginning at the top and proceeding downwards to the bottom. In this operation two workmen are required; one to supply the stucco, the other to apply the plumb-rule and straight-edge. When these are truly formed, other screeds must be made in a vertical direction, about four or five feet apart, unless apertures in the wall prevent it, in which case they must be formed as near together as possible. When the screeding is finished, compo is prepared in larger quantities, and both the workmen spread

it with their trowels over the wall in the space left between each pair of screeds. When this operation is complete, the straight-edge is applied, and dragged from the top to the bottom of each pair, to remove whatever superfluous stucco may project above the screeds. If there be any hollow places, fresh stucco is applied, and the straight-edge is again drawn over the spot, till the compo is brought even to the face of the screeds, and the whole is level with the edge of the rule. Another interval is then filled up, and the workmen thus proceed till the whole of the wall is covered. The wall is finished by floating, that is, hardening the surface, by sprinkling it with water, and rubbing it with the common wood-float, which is performed similarly to trowelling stucco.

This description of compo is frequently used by plasterers for cornices and mouldings, in the same manner as described in common plastering; but if the workman finds it necessary, he may add a small quantity of plaster of Paris, to make it fix the better while running or working the mould. Such addition is not, however, calculated to give strength to the stucco, and is only made through the necessity of having a quick set.

In the year 1796, Mr Parker obtained a patent for a cement that is impervious to water, and which may be successfully employed in ice-houses, cisterns, tanks, &c. In his specification Mr Parker states, that "nodules of clay, or argillaceous stone, generally contain water in their centre, surrounded by calcareous crystals, having veins of calcareous matter. They are formed in clay, and are of a brown colour like the clay." These nodules he directs should, after being broken into small pieces and burnt in a kiln, with a heat that is nearly sufficient to vitrify them, be reduced to powder: when two measures of water added to five of this powder, will produce *tarras*. Lime and other matters may be added or withheld at pleasure; and the proportion of water may be varied.

The term of the patent being now expired, many other manufactories of this cement have been established, which produce it of equal goodness, and some of them of rather better colour, which is of importance, since the fresco-painting, or white-wash, laid on Mr Parker's composition, is soon taken off by the rain, and leaves the walls of a dingy and unpleasant appearance.

The fresco-painting, or staining, is laid on the walls covered with this cement, to give them the appearance of

stone buildings; and is performed by diluting sulphuric acid, (*oil of vitriol,*) with water, and adding fluid ochres, &c. of the required tint.

When stucco is washed over with this mixture, the affinity existing in the iron of the cement ceases; and the acid and colour suspended in and upon the stucco are fixed. When dexterously managed, the surface assumes the appearance of an ashlar bond of masonry.

Scagliola is a distinct branch of plastering, discovered or invented, and much used in Italy, and thence introduced into France, where it obtained its name; the late Mr H. Holland, who introduced it into England, engaged artists from Paris, some of whom, finding a demand for their labour, remained in this country, and instructed the natives in the art.

Columns and pilasters are executed in this branch of plastering in the following manner: A wooden cradle, composed of thin strips of deal, or other wood, is made to represent the column designed; but about two inches and a half less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking-up coat of lime, and hair. When this is quite dry, the artists in scagliola commence operations, by imitations of the most rare and precious marbles, with astonishing and delusive effect; indeed, as the imitation takes as high a polish, and feels as cold and hard as the most compact and solid marble, nothing short of actual fracture can possibly discover the counterfeit.

In preparing the scagliola, the workman selects, breaks, and calcines the purest gypsum, and as soon as the largest fragments, in the process of calcination, lose their brilliancy, withdraws the fire, and passes the calcined powder through a very fine sieve, and mixes it, as required for use, with a solution of glue, isinglass, &c. In this solution the colours required in the marble to be imitated are diffused; but when the work is to be of various colours, each colour is prepared separately, and afterwards mingled and combined, nearly in the same manner as a painter mixes on his palette the primitive colours to compose the different tints.

When the powdered gypsum is prepared, it is laid on the shaft of the intended column, over the pricked-up coat of lime and hair, and is then floated with moulds of wood, made to the requisite size: the artist uses the colours necessary for the imitation during the floating, by which means

they mingle and incorporate with the surface. To obtain the glossy lustre, so much admired in works of marble, the workman rubs the work with one hand with a pumice-stone, while with the other he cleans it with a wet sponge: he next polishes it with tripoli, charcoal, and a piece of fine linen; afterwards with a piece of felt dipped in a mixture of oil and tripoli, and finally completes the work by the application of pure oil. This imitation is, certainly, the most complete that can be conceived; and when the bases and capitals are made of real marble, as is the common practice, the deception is beyond discovery. If not exposed to the weather, it is, in point of durability, little inferior to real marble, retains its lustre full as long, and is not one-eighth of the expense of the cheapest kind.

There is another species of plastering, used in the decorative parts of architecture, and for the frames of pictures, looking-glasses, &c. which is a perfectly distinct branch of the art. This composition, which is very strong, and, when quite dry, of a brownish colour, consists of the proportion of two pounds of powdered whiting, one pound of glue in solution, and half a pound of linseed oil, mixed together, and heated in a copper, and stirred with a spatula till the whole is incorporated. When cool, it is laid upon a stone, covered with powdered whiting, and beaten till it assumes a tough and firm consistence; after which it is covered with wet cloths, to keep it fresh, till required for use.

The ornaments to be cast in this composition are modelled in clay, as in common plastering, and afterwards a cameo, or mould, is carved in box-wood. This carving requires to be done with the utmost care, otherwise the symmetry of the ornament which is to be cast from it will be spoiled. The composition, when required for use, is cut with a knife into pieces of the requisite size, and forced into the mould; after which it is put into a press, worked by an iron screw, and still further compressed. When the mould is taken from the press, the composition, which is generally cast about a foot in length, is dislodged from the mould, and the superfluous parts pared off with a knife, and cast into the copper for the next supply.

The ornaments thus formed, are glued upon wooden, or other grounds, or fixed by means of white lead, &c.; after which they are painted or gilt, according to the purposes for which they are intended. This composition is at least 80 per cent. cheaper than carving, and, in most cases, equally calculated to answer all the purposes of the art.

It is much to be wished, that the art of plastering could be restored to its ancient perfection; for the Romans possessed an art of rendering works of this kind much more firm and durable than can be accomplished at the present time.

The specimens of ancient Roman plastering still visible, which have not been injured by force, are found to be firm and solid, free from cracks or crevices, and as smooth and polished on the surface as when first applied. The sides and bottoms of the Roman aqueducts were lined with this plastering, and endured many ages.

At Venice, some of the roofs of houses, and the floors of rooms, are covered with a sort of plaster of later date, and yet strong enough to endure the sun and weather for several ages, without either cracking or spoiling.

The method of making the Venetian composition is not known in England; but such might probably be made by heating the powder of gypsum over a fire, and when boiling, which it will do without the aid of water, or other fluid, mixing it with resin, or pitch, or both together, with common sulphur, and the powder of sea-shells. If these be mixed together, water added to it, and the composition kept on the fire till the instant of its being used, it is not improbable that the secret may be discovered. Oil of turpentine and wax, which are the common ingredients in such cements as are accounted firmest, may also be tried as additions; as also may strong ale wort, which is by some directed to be used instead of water, to make mortar of lime-stone of more than ordinary strength.

SLATING.

This branch of building, which is principally employed in the covering of roofs, is not unfrequently combined with that of plastering. The slates chiefly used in London are brought from the quarries at Bangor, in Caernarvonshire, which supply all parts of the United Kingdom. Another kind of slate, of a pale blue-green colour, is used, and most esteemed, being brought from Kendal, in Westmoreland, called *Westmoreland slates.* These slates are not large; but of good substance and well calculated to give a neat appearance to a roof. The Scottish slate, which assimilates in size and quality to a slate from Wales, called *ladies,* is in little repute.

Slaters class the Welsh slates in the following order:

		Ft.	In.		Ft.	In.
Doubles,	average size,	1	1	by	0	6
Ladies,	———	1	3	—	0	8
Countesses,	———	1	8	—	0	10
Duchesses,	———	2	0	—	1	0
Welsh rags,	———	3	0	—	2	0
Queens,	———	3	0	—	2	0
Imperials,	———	2	6	—	2	0
Patent slate,	———	2	6	—	2	0

The *doubles* are made from fragments of the larger kinds, and derive their name from their diminutive size. *Ladies* are similarly obtained. *Countesses* are a gradation above ladies; and *duchesses* above countesses.

Slate, like most other stony substances, is separated from its bed by the ignition of gunpowder. The blocks, thus obtained, are, by the application of wedges, reduced into layers, called *scantlings*, from four to nine inches in thickness, and of any required length and breadth, which are afterwards sawn to the respective sizes by machinery. The blue, green, and purple, or darker kinds of slate, are, in general, found capable of being split into very thin laminæ, or sheets; but those of the white or brownish free-stone kind, can seldom be separated or divided so fine; consequently, these last form heavy, strong, thick coverings, proper for buildings in exposed situations, such as barns, stables, and other out-houses.

The instruments used in splitting and cleaning slates are, slate-knives, axes, bars, and wedges; the three first being used to reduce the slates into the required thicknesses, and the last to remove the inequalities from the surface.

Imperial slating is particularly neat, and may be known by having its lower edge sawn; whereas all other slates used for covering are chipped square on their edges only.

Patent slate was first brought into use by Mr Wyatt, the architect; but a patent was never obtained. It derives its name from the mode adopted to lay it on roofs; it may be laid on a rafter of much less elevation than any other, and is considerably lighter, by reason of the laps being less than is necessary for the common sort of slating. This slating was originally made from *Welsh rags*; but is now very frequently made from *Imperials*, which render it lighter, and also somewhat neater in appearance.

Westmoreland slate, from the experiments made by the late Bishop of Landaff, appears to differ little in its natural composition from that obtained from Wales. It must, however,

be remarked, that this kind of slate owes its lightness, not so much to any diversity in the component parts of the stone, as to the thinness to which it is reduced by the workmen; consequently, it is not so well calculated to resist violent winds as those which are heavier.

Slates, when brought from the quarry, are not sufficiently square for the slater's use; he therefore picks up and examines the slates separately, and observes which is the strongest and squarest end; then, seating himself, he holds the slate a little slanting upon, and projecting about an inch over the edge of a small block of wood, which is of the same height as his seat, and cuts away and makes straight one of its edges; then, with a slip of wood, he gauges and cuts off the other edge parallel to it, and squares the end. The slate is now considered prepared for use, with the exception of perforating through its opposite ends two small holes, for the reception of the nails which are to confine it to the roof. Copper and zinc nails, or iron nails tinned, are considered the best, being less susceptible of oxidation than nails made of bar iron.

Before we proceed further with the operations necessary in the slating of buildings, we shall give some account of the tools used by this class of artificers.

Slaters' tools are very few, which sometimes are found by the masters, and sometimes by the men. The tool called the *saixe*, is made of tempered iron, about sixteen inches in length, and two inches in width, somewhat bent at one end, with a handle of wood at the other. This tool is not unlike a large knife, except that it has on its back a projecting piece of iron, about three inches in length, drawn to a sharp point. This tool is used to chip or cut all the slates to the required sizes.

The *ripper* is also of iron, about the same length as the saixe; it has a very thin blade, about an inch and three-quarters wide, tapered somewhat towards the top, where a round head projects over the blade about half an inch on each side: it has also two little round notches in the two internal angles at their intersections. The handle of this tool is raised above the blade by a shoulder, which enables the workman to hold it firm. This instrument is used in repairing old slating, and the application consists in thrusting the blade under the slates, so that the head, which projects, may catch the nail in the little notch at its intersection, and enable the workman to draw it out. During this

operation the slate is sufficiently loosened to allow of its being removed, and another inserted in its place.

The *hammer*, which is somewhat different in shape to the ordinary tool of that name, is about five inches in height on the hammer or driving part, and the top is bent back, and ground to a tolerably sharp point, its lower or flat end, which is quite round, being about three-quarters of an inch in diameter. On this side of the driving part is a small projection, with a notch in the centre, which is used as a claw to extract such nails as do not drive satisfactorily.

The *shaving-tool* is used for getting the slates to a smooth face for skirtings, floors of balconies, &c. It consists of an iron blade, sharpened at one of its ends like a chisel, and mortised through the centre of two round wooden handles, one fixed at one end, and the other about the middle of the blade. The blade is about eleven-inches long, and two inches wide, and the handle is about ten inches long, so that they project about four inches on each side of the blade. In using this tool the workman places one hand on each side of the handle that is in the middle of the blade, and allows the other to press against both his wrists. In this manner he removes all the uneven parts from off the face of the slate, and gets it to a smooth surface.

The other tools used by the slater consists of chisels, gouges, and files of all sizes; by means of which he finishes the slates into mouldings and other required forms.

In slating roofs, it is necessary to form a base or floor for the slates to lay compactly and safely upon; for *doubles* and *ladies*, boarding is required, which must be laid very even, with the joints close, and properly secured by nails to the rafters. This being completed, the slater provides himself with several slips of wood, called *tilting fillets*, about ten inches and a half wide, and three-quarters of an inch thick on one edge, and chamfered to an arris on the other, which he nails down all round the extreme edges of the roof, beginning with the hips, if any, and if not with the sides, eaves, and ridge. He next selects the largest of the slates, and arranges them regularly along the eaves with their lower edges to a line, and nails them to the boarding. This part of the work being completed, he takes other slates to form the bond to the under sides of the eaves, and places them under those previously laid, so as to cross and cover all their joints. Such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for support on the weight of those above

them, and their own weight on the boarding. The *countesses* and all other description of slates, when intended to be laid in a good manner, are also laid on boards.

When the slater has finished the eaves, he strains a line on the face of the upper slates, parallel to its outer edge, and as far from it as he deems sufficient for the lap of those he intends shall form the next course, which is laid and nailed even with the line, crossing the joints of the upper slates of the eaves. This lining and laying is continued close to the ridge of the roof, observing throughout to cross the different joints, by laying the slates one above another. The same system is uniformly followed in laying all the different sorts of slates, with the exception of those called *patent slates*, as are hereafter explained.

The largest kinds of slate are found to lay firm on *battens*, which are, consequently, much employed, and produce a very considerable saving of expense in large buildings. A batten is a narrow portion of deal, about two inches and a half, or three inches wide; four of them being commonly procured from an eleven inch board.

For countess slates, battens three-quarters of an inch thick will be of adequate substance; but for the larger and heavier kinds, inch battens will be necessary. In battening a roof for slates, the battens are not placed at an uniform distance from each other, but so as to suit the length of the slates; and as these vary as they approach the apex, or ridge of the roof, it follows that the slater himself is the best judge where to fix them, so as best to support the slates.

A roof, to be covered with patent slates, requires that the common rafters be left loose upon their purlines, as they must be so arranged that a rafter shall lie under every one of the meeting joints. Neither battening nor boarding is required for these slates. The number of rafters will depend on the width of the slates; hence if they be of a large size, very few will suffice. This kind of slating is likewise commenced at the eaves; but no crossing or bonding is required, as the slates are laid uniformly, with each end reaching to the centre of the rafter, and butted up to each other throughout the length of the roof. When the eaves-course is laid, the slates which compose it are screwed down to the rafters by two or three strong inch and half screws at each of their ends. A line is then strained about two inches below the upper edge, in order to guide the laying of the next course, which is laid with its lower edge touching the line. This lining, laying with a lap, and screwed

down, is continued till the roof is completely covered. The joints are then secured by filletting, which consists in covering all the meeting-joints with fillets of slate, bedded in glazier's putty, and screwed down through the whole into the rafters. The fillets are usually about three inches wide, and of a length proportionate to that of the slates, whose joints they have to cover. These fillets are solidly bedded in the putty, and their intersecting joints are lapped similar to those of the slates. The fillets being so laid, and secured by one in the middle of the fillet and one in each lap, are next neatly pointed all round their edges with more putty, and then painted over with the colour of the slate. The hips and ridges of such slating are frequently covered by fillets, which produces a very neat effect; but lead, which is not much dearer, is by far the best kind of covering for all hips and ridges. The patent slating may be laid so as to be perfectly water-tight, with an elevation of the rafters considerably less than for any other slate or tile covering. The rise in each foot of length in the rafter is not required to be more than two inches, which, in a rafter of fifteen feet, will amount to only two feet six inches; a rise scarcely perceptible from the ground.

Slating is performed in several other ways, but the principles already explained embrace the most of them. Some workmen shape and lay their slates in a lozenge form. This kind of work consists in getting all the slates to an uniform size, of the shape of a geometrical square. When laid on the roof, which must be boarded, they are bonded and lapped as in common slating, observing only to let the elbow, or half of the square, appear above each slate that is next beneath it, and be regular in the courses all over the roof. One nail or screw only can be used for such slating; hence it soon becomes dilapidated. It is commonly employed in places near to the eye, or where particular neatness is required.

It has been ascertained, that a slate one inch thick will, in an horizontal position, support as much, in weight, as five inches of Portland stone similarly suspended. Hence slates are now wrought and used in galleries, and other purposes, where it is essential to have strength and lightness combined.

Slates are also fashioned into chimney-pieces; but are incapable of receiving a polish like marble. It makes excellent skirtings of all descriptions, as well as casings to walls, where dilapidations, or great wear and tear are to be ex-

pected. For these purposes it is capable of being fixed with joints, equally as neat as wood: and may, if required, be painted over so as to appear like it. Stair-cases may also be executed in slate, which will produce a resemblance of marble.

MENSURATION OF PLASTERERS' AND SLATERS' WORK.

Plasterers' work is executed by the yard square; and the dimensions are taken in feet and inches.

If a room consists of more than four quoins, the additional corners must be allowed at per foot run.

In measuring ceilings with ribs, the superficies must be taken for plain work; then an allowance must be made for each mitre, and the ribs must be valued at so much per foot run, according to the girth; or by the foot superficial, allowing moulding work.

In measuring common work the principal things to be observed are as follow:—first, to make deductions for chimneys, windows, and doors; secondly, to make deductions for rendering upon brick-work, for doors and windows; thirdly, if the workman find materials for rendering between quarters, one-fifth must be added for quarters; but if workmanship only is found, the whole must be measured as whole work, because tke workman could have performed the whole much sooner if there had been no quarters; fourthly, all mouldings in plaster-work are measured by the foot superficial, the same as joiners, by girting over the mouldings with a line.

Slaters' work is measured and reduced into squares, containing 100 feet superficial. If in measuring the slating on a roof, it be hipped on all sides with a flat at top, and the plan of the building be rectangular, add the length and breadth of two adjoining sides of the eaves, and the length and breadth of two adjoining sides at the flat together, multiply the sum by the breadth of the slope, and the product will give the area of the space that is covered. Add the number of square feet produced, by multiplying the girts of the roof by the length of the slates at thc eaves; to the area also, for the trouble of putting on the double row of slates, add the number of square feet produced by multiplying the length of the hips by one foot in breadth, and the sum will be the whole contents, and yield a compensation for the trouble and waste of materials. If there be no flats, add the two adjoining sides and twice the length of the ridge for the length; multiply the sum by the breadth of the slips, for

the area of the space covered, and add the allowances as before.

Another plan is to allow in addition to the nett dimensions of the work, six inches for all the eaves, and four inches for the hips.

All faced work in slate skirting, stair-cases, galleries, &c. is charged by the foot superficial, without any addition.

PLUMBING,

Is the art of casting and working in lead, and using the same in the covering and for other purposes in building.

To the plumber is also confided the pump-work, as well as the making and forming of cisterns and reservoirs, large or small closets, &c. for the purposes of domestic œconomy. The plumber does not use a great variety of tools, because the ductility of the metal upon which he operates does not require it.

The tools used consist of an iron hammer, rather heavier than a carpenter's, with a short thick handle; two or three wooden mallets of different sizes; and a dressing and flatting tool.

This last is of beech, about eighteen inches long, and two inches square, planed smooth and flat on the under surface, rounded on the upper, and one of its ends tapered off round as a handle. With this tool he stretches out and flattens the sheet-lead, or dresses it to the shape required, using first the flat side, then the round one, as occasion may require.

The plumber has also occasion for a jack and trying plane, similar to that of the carpenter.

With this he reduces the edges of sheet-lead to a straight line, when the purposes to which it is to be applied require it.

Also a chalk line, wound upon a roller, for marking out the lead into such breadths as he may want.

His cutting tools consist of a variety of chisels and gouges as well as knives.

The latter of these are used for cutting the sheet-lead into [illegible] pieces after it has been marked out by the chalk [illegible] different sizes; ladles of three or four sizes, for [illegible]older; and an iron instrument called *grozing*

These grozing-irons are of several sizes, generally about twelve inches in length, tapered at both ends, the handle end being turned quite round, to allow of its being firmly held while in use : the other end is a bulb of a spindle, or spherical shape, of a size proportioned to the soldering intended to be executed. They are, when required for use, heated to redness.

The plumber's measuring rule is two feet in length, divided into three equal parts of eight inches each; two of its legs are of box-wood, duodecimally divided; and the third consists of a piece of slow tempered steel, attached to one of the box legs by a pivot on which it turns, and falls, when not in use, into a groove cut in such leg for its reception. This steel leg can be passed into places where the others cannot enter; and it is also useful for occasionally removing the oxide or any other extraneous matters from the surface of the heated metal.

Scales and weights are also necessary; and he must be supplied with centre-bits of all sizes; and a stock to work them, for the purpose of making perforations in lead or wood, through which he may want to insert pipes, &c. Compasses, to strike circular pieces, to line or cover figures of that shape, are occasionally required.

Lead is obtained from ore, and, from its being generally combined with sulphur, it has been denominated "*sulphuret.*" After the ore has been taken from its bed it is smelted, first being picked, in order to separate the unctuous and rich, or genuine ore from the stony matrix, and other impurities; the picked ore is then pounded under stampers worked by machinery, and afterwards washed to carry off the remainder of the matrix, which could not be separated in picking. It is next put into a reverberatory furnace, to be *roasted;* during which operation it is repeatedly stirred, to facilitate the evaporation of the sulphur. When the surface begins to assume the appearance of a paste, it is covered with charcoal, and well shaken together: the fire is then increased and the purified lead flows down on all sides into the basin of the furnace, whence it runs off into moulds prepared for its reception. The moulds are capable of receiving 154 lbs. of lead each, and their contents, when cool, are, in the commercial world, called *pigs.*

Lead is of a bluish-white colour, and when newly melted, or cut, is quite bright; but it soon becomes tarnished on exposure to the atmosphere, assuming first a dirty grey colour, and afterwards becomes white. It is capable of

being hammered into very thin plates, and may be drawn into wire; but its tenacity is very inferior to that of other metals; for a leaden wire, the hundred and twentieth part of an inch in diameter, is only capable of supporting about 18 lbs. without breaking. Lead, next to tin, is the most fusible of all metals; and if a stronger heat be applied, it boils and evaporates. If cooled slowly, it crystallizes. The change of its external colour is owing to its gradual combination with oxygen, which converts its exterior surface into an oxyd. This outward crust, however, preserves the rest of the metal for a long time, as the air can penetrate but very slowly.

Lead is not acted upon immediately by water, though that element greatly facilitates the action of the air upon it: for it is known that, when lead is exposed to the atmosphere, and kept constantly wet, the process of oxidation takes place much more rapidly than it does under other circumstances: hence the white crust that is to be observed on the sides of leaden vessels containing water, just at the place where the surface of the water terminates.

Lead is purchased by plumbers in *pigs*, and they reduce it into sheets or pipes, as they have occasion. Of sheet-lead they have two kinds, cast and milled. The former is used for covering flat roofs of buildings, laying of terraces, forming gutters, lining reservoirs, &c.: and the latter, which is very thin, for covering the hips and ridges of roofs. This last they do not manufacture themselves, but purchase it of the lead merchants, ready prepared.

For the casting of sheet-lead, a copper is provided, and well fixed in masonry, at the upper end of the workshop, near the mould or casting table, which consists of strong deal boards, well joined together, and bound with bars of iron at the ends. The sides of this table, of which the shape is a parallelogram, vary in size from four to six feet in width, and from 16 to 18 feet and upwards in length, and are guarded by a frame or edging of wood, 3 inches thick, and 4 or 5 inches higher than the interior surface, called the *shafts*. This table is fixed upon firm legs, strongly framed together, about 6 or 7 inches lower than the top of the copper. At the upper end of the mould, nearest the copper, is a box, called the *pan*, which is adapted in its length to the breadth of the table, having at its bottom a long horizontal slit, from which the heated metal is to issue, when it has been poured in from the copper. This box moves upon rollers along the surface of the rim of the table, and is put in mo-

tion by means of ropes and pulleys, fixed to beams above. While the metal is melting, the surface of the mould, or table, is prepared by covering it with a stratum of dry and clean sand, regularly smoothed over with a kind of rake, called a *strike*, which consists of a board about 5 inches broad, and rather longer than the inside of the mould, so that its ends, which are notched about two inches deep, may ride upon the shafts. This being passed down the whole length of the table, reduces the sand to an uniform surface. The pan is now brought to the head of the table, close to the copper, its sides having previously been guarded by a coat of moistened sand, to prevent its firing from the heat of the metal, which is now put in by ladles from the copper.

These pans, or boxes, it must be observed, are made to contain the quantity of melted lead which is required to cast a whole sheet at one time; and the slit in the bottom is so adjusted as to let out, during its progress along the table, just as much as will completely cover it of the thickness and weight per foot required. Every thing being thus prepared, the slit is opened, and the box moved along the table, dispensing its contents from the top to the bottom, and leaving in its progress a sheet of lead of the desired thickness. When cool, the sheet is rolled up and removed from the table, and other sheets are cast, till all the metal in the copper is exhausted. The sheets thus formed are then rolled up and kept for use.

In some places, instead of having a square box upon wheels, with a slit in the bottom, the pan consists of a kind of trough, being composed of two planks nailed together at right angles, with two triangular pieces fitted in between them, at their ends. The length of this pan, as well as that of the box, is equal to the whole breadth of the mould. It is placed with its bottom on a bench at the head of the table, leaning with one side against it: to the opposite side is fixed a handle, by which it may be lifted up in order to pour out the liquid metal. On the side of the pan next the mould are two iron hooks, to hold it to the table, and prevent it from slipping while the metal is being poured into the mould.

The mould, as well as the pan, is spread over, about two inches thick, with sand, sifted and moistened, and rendered perfectly level by moving over it the strike, and smoothing it down with a plane of polished brass, about a quarter of an inch thick, and nine inches square, turned up on the edges.

Before they proceed to casting the lead, the strike is made

ready by tacking two pieces of old hat on the notches, or by covering the notches with leather cases, so as to raise the under side of the strike about an eighth of an inch, or more, above the sand, according to the proposed thickness of the sheet. The face or under side of the strike is then smeared with tallow, and laid across the breadth of the mould, with its ends resting on the shafts. The melted lead is then put into the pan with ladles; and, when a sufficient quantity has been put in, the scum is swept off with a piece of board, and suffered to settle on the coat of sand, to prevent its falling into the mould, when the metal is poured out. It generally happens that the lead, when first taken from the copper, is too hot for casting; it is therefore suffered to cool in the pan, till it begins to stand with a shell or wall on the sand with which the pan is lined. Two men then take the pan by the handle, or one of them takes it by means of a bar and chain fixed to a beam in the ceiling, and turn it down, so that the metal runs into the mould: while another man stands ready with the strike, and, as soon as all the metal is poured in, sweeps it forward and draws the residue into a trough at the bottom, which has been prepared to receive it. The sheet is then rolled up, as before.

In this mode of operation, the table inclines in its length about an inch, or an inch and a half, in the length of sixteen or seventeen feet, or more, according to the required thickness of the sheets; the thinner the sheet the greater the declivity, and *vice versá*. The lower end of the mould is also left open, to admit of the superfluous metal being thrown off.

When a cistern is to be cast, the size of the four sides is measured out; and the dimensions of the front having been taken, slips of wood, on which the mouldings are carved, are pressed upon the sand. Figures of birds, beasts, &c. are likewise stamped in the internal area, by means of leaden moulds. If any part of the sand has been disturbed in doing this, it is made smooth, and the process of casting goes on as for plain sheets; except that, instead of rolling up the lead when cast, it is bent into four sides, so that the two ends, when they are soldered together, may be joined at the back; the bottom is afterwards soldered up.

The lead which lines the Chinese tea-boxes is reduced to a thinness which our plumbers cannot, it is said, approach. The following account of the process was communicated by an intelligent East-Indian, in a letter which appeared in the Gentleman's Magazine. "The caster sits by

a pot containing the melted metal, and has two large stones, the lower one fixed and the upper one movable, having their surfaces of contact ground to each other, directly before him. He raises the upper stone by pressing his foot upon its side, and with an iron ladle pours into the opening a sufficient quantity of the fluid metal. He then lets fall the upper stone, and thus forms the lead into an extremely thin and irregular plate, which is afterwards cut into its required form."

Cast sheet-lead, used for architectural purposes, is technically divided into 5 lb. 5½ lb. 6 lb. 6½ lb. 7 lb. 7½ lb. 8 lb. and 8½ lb.; by which is understood, that every superficial foot is to contain those respective weights, according to the price agreed upon.

The milled-lead, used by plumbers, is very thin, seldom containing more than 5 lb. to the foot. It is by no means adapted to gutters or terraces, nor, indeed, to any part of a building that is much exposed either to great wear or to the effects of the sun's rays: in the former case, it soon wears away; in the latter, it expands and cracks. It is laminated in sheets of about the same size as those of cast-lead, by means of a roller, or flatting-mill.

Lead-pipes, besides the various ways of manufacture described in page 370, vol. i. are sometimes made of sheet-lead, by beating it on round wooden cylinders of the length and dimensions required, and then soldering up the edges.

Solder is used to secure the joints of work in lead, which by other means would be impossible. It should be easier of fusion than the metal intended to be soldered, and should be as nearly as possible of the same colour. The plumber therefore uses, what is technically called, *soft solder*, which is a compound of equal parts of tin and lead, melted together and run into moulds. In this state it is sold by the manufacturer by the pound.

In the operation of soldering, the surfaces or edges intended to be united are scraped very clean, and brought close up to each other, in which state they are held by an assistant, while the plumber applies a little resin on the joints, in order to prevent the oxidation of the metal. The heated solder is then brought in a ladle and poured on the joint; after which it is smoothed and finished by rubbing it about with a red-hot soldering iron, and when completed is made smooth by filing.

In the covering of roofs or terraces with lead, (the sheets never exceeding six feet in breadth,) it becomes necessary in

large surfaces to have joints, which are managed several ways, but in all, the chief object is to have them water-tight. The best plan of effecting this, is to form *laps* or roll joints, which is done by having a roll, or strip of wood, about two inches square, but rounded on its upper side, nailed under the joints of the sheets, where the edges lap over each other; one of these edges is to be dressed up over the roll on the inside, and the other is to be dressed over them both on the outside, by which means the water is prevented from penetrating. No other fastening is requisite than what is required from the hammering of the sheets together down upon the flat; nor should any other be resorted to, when sheet-lead is exposed to the vicissitudes of the weather; because it expands and shrinks, which, if prevented by too much fastening, would cause it to crack and become useless. It sometimes, however, occurs, that rolls cannot be used, and then the method of joining by *seams* is resorted to. This consists in simply bending the approximate edges of the lead up and over each other, and then dressing them down close to the flat, throughout their length. But this is not equal to the roll, either for neatness or security.

Lead flats and gutters should always be laid with a current, to keep them dry. About a quarter of an inch to the foot run is a sufficient inclination.

In laying gutters, &c. pieces of milled-lead, called *flushings*, about eight or nine inches wide, are fixed in the walls all round the edges of the sheet-lead, with which the flat is covered, and are suffered to hang down over them, so as to prevent the passage of rain through the interstice between the raised edge and the wall. If the walls have been previously built, the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flushings are not only inserted into the crack at the upper sides, but their lower edges are likewise dressed over those of the lead in the flat, or gutter. When neither of these modes can be resorted to, the flushings are fastened by wall-hooks, and their lower edges dressed down as before.

Drips in flats, or gutters, are formed by raising one part above another, and dressing the lead, as already described, for covering the rolls. They are resorted to when the gutter or flat exceeds the length of the sheet; or sometimes for convenience. They are also an useful expedient to avoid soldering the joints.

Sheet-lead is also used in the lining of reservoirs, which

are made either of wood or masonry. As these conveniences are seldom in places subject to material change of temperature, recourse may be had to the soldering, without fear of its damaging the work, by promoting a disposition to crack.

The pumps which come under the province of the plumber, are confined generally to two or three kinds, used for domestic purposes, of which the suction and lifting pumps are the chief: these, as well as water-closets, are manufactured by a particular set of workmen, and sold to the plumber, who furnishes the lead pipes, and fixes them in their places.

Plumber's work is generally estimated by the pound, or hundred weight; but the weight may be discovered by measurement, in the following manner: sheet-lead used in roofing and guttering is commonly between seven and twelve pounds to the square foot; but the following table exhibits the particular weight of a square foot for each of the several thicknesses.

Thickness.	Pounds to a sq. ft.	Thickness.	Pounds to a sq. ft.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	.21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds, and thousandth parts of a pound; so that the weight of a square foot of 1-10th of an inch thick, 10-100ths, is 5 lbs. and 899 thousandth parts of a pound; and the weight of a square foot 1-9th of an inch in thickness, is 6 pounds and 554 thousandths of a pound. Leaden pipe of an inch bore is commonly 13 or 14 lbs. to the yard in length.

GLAZING.

The business of this class of artificers consists in putting glass into sashes and casements. Glazier's work may be classed under three distinct heads, sash-work, lead-work, and fret-work.

The tools requisite for the performance of the first of these departments are, a diamond, a ranging lath, a short lath, a square, a rule, a glazing-knife, a cutting-chisel, a beading-hammer, a duster, and sash-tool; and in addition, for stopping in squares, a hacking-knife and hammer.

The diamond is a speck of that precious stone, polished to a cutting point, and set in brass on an iron socket, to receive a wooden handle, which is so set as to be held in the hand in the cutting direction. The top of the handle goes between the root of the fore-finger and the middle finger, and the hinder part between the point of the fore-finger and thumb; there is, in general, a notch in the side of the socket, which should be held next to the lath. Some diamonds have more cuts than one. Plough diamonds have a square nut on the end of the socket, next the glass, which, on running the nut square on the side of the lath, keeps it in the cutting direction.

Glass binders have these plough diamonds without long handles, as, in cutting their curious productions, they cannot apply a lath, but direct them by the point of their middle finger, gliding along the edge of the glass.

The ranging lath must be long enough to extend rather beyond the boundary of the table of glass.

Ranging of glass is the cutting it in breadth as the work may require, and is best done by one uninterrupted cut from one end to the other.

The square is used in cutting the squares from the range, that they may with greater certainty be cut at right angles. The glazing-knife is used for laying in the putty in the rebates of the sash, for binding in the glass, and for finishing the front putty.

Of the glass used in building, three qualities are in common use, denominated *best*, *second*, and *third*.

The best is that which is the purest metal and free of blemishes, as blisters, specks, streaks, &c.; the second is inferior, from its not being so free from these blemishes; and the third are still inferior, both in regard to quality and colour, being of greener hue.

They are all sold at the same price per crate; but the number of tables varies according to the quality. Best twelve, second fifteen, and third eighteen tables.

These tables are circular when manufactured, and about four feet in diameter, having in the centre a knot, to which, in the course of the process, the flashing rod was fixed; but for the safety of carriage, and convenience of handling, as

well as utility in practice, a segment is cut off about four inches from the knot. The large piece with the knot still retains the name of *table;* the smaller piece is technically called *a slab.* From these tables being of a given size, it is reasonable to suppose that, when the dimensions of squares are such as cut the glass to waste, the price should be advanced.

A superior kind of glass may be obtained at some of the first houses in London, which is very flat, and of large dimensions; some of it being 2 feet 8 inches by 2 feet 1 inch; these are sold only in squares.

Rough glass is well adapted to baths, and other places of privacy; one side is ground with emery or sand, so that no objects can be seen through it, though the light be still transmitted.

The glass, called *German-sheet,* is of a superior kind, as it can be had of much larger dimensions than common glass; it is also of a purer substance, and for these reasons, is frequently appropriated to picture frames. Squares may be had at the astonishing size of 3 feet 8 inches, by 3 feet 1 inch, and 3 feet 10 inches by 2 feet 8 inches, and under.

The glass is first blown in the form of a globe, and afterwards flatted in a furnace, in consequence of which it has a very forbidding appearance from the outside, the surface being uneven.

Plate-glass is the most superior in quality, substance, and flatness, being cast in plates and polished. The quantity of metal it contains must be almost, if not altogether, colourless, that sort which is tinged being of an inferior quality.

Plate-glass, when used in sashes, is peculiarly magnificent; and it can be had of larger dimensions than any other kind of glass.

Stained-glass is of different colours, as red, orange, yellow, green, blue, and purple.

These colours are fixed by burning, and are as durable as the glass.

Glass can be bent to circular sweeps, which is much used in London for shop windows, and is carried to great perfection in covers, for small pieces of statuary, &c.

The application of stained-glass to the purposes of glazing is called *fret-work.* This description of work consists of working ground and stained-glass in fine lead, into different patterns. In many cases family arms and other devices are worked in it. It is a branch capable of great improvement, but at present is much neglected. Old pieces are very much

esteemed, though the same expense would furnish elegant modern productions. They are placed in halls and staircase windows, or in some particular church windows. In many instances they are introduced where there is an unpleasant aspect, in a place of particular or genteel resort.

Lead-work is used in inferior offices, and is in general practice all through the country. Frames intended to receive these lights are made with bars across, to which the lights are fastened by leaden bars, called saddle bars; and where openings are wanted, a casement is introduced either of wood or iron. Sometimes a sliding frame answers the same purposes. Church windows are generally made in this manner, in quarries or in squares.

The tools with which this work is performed are, in addition to the foregoing, as follow:

A *vice*, with different cheeks and cutters, to turn out the different kinds of lead, as the magnitude of the window or the squares may require.

The German vices, which are esteemed the best, are furnished with moulds, and turn out lead in a variety of sizes. The bars of lead cast in these vices are received by the mill, which turns them out with two sides parallel to each other, and about $\frac{3}{8}$ of an inch broad, with a partition connecting the two sides together, about $\frac{1}{8}$ of an inch wide, forming on each side a groove, nearly $\frac{2}{61}$ by $\frac{1}{8}$ of an inch, and about 6 feet long.

Besides a vice and moulds, there are a *setting-board*, *latterkin*, *setting-knife*, *resin-box tin*, *glazing-irons*, and *clips*.

The *setting-board* is that in which the ridge of the light is marked and divided into squares, struck out with a chalk line, or drawn with a lath, which serves to guide the workmen. One side and end is squared with a projecting bead or fillet.

The *latterkin* is a piece of hard wood pointed, to run in the groove of the lead, and widen it for the easier reception of the glass.

The *setting-knife* consists of a blade with a round point, loaded with lead at the bottom, and terminating in a long square handle. The square end of the handle serves to force the square of glass tight in the lead. All the intersections are soldered on both sides, except the outside joints of the outer sides, that is, where they come to the outer edge. These lights should be cemented by pouring thin paint along the lead bars, and filling up the chasms with dry whiting, to which, after the oil in the paint has se-

creted a little, a little more dry whiting, or white-lead, must be added. This will dry hard, and resist the action of the atmosphere.

MENSURATION OF GLAZIERS' WORK.

Glaziers' work is measured by superficial feet, and the dimensions are taken in feet, tenths, &c. For this purpose their rules are generally divided into decimal parts, and their dimensions squared according to decimals. Circular or oval windows are measured as if they were rectangular; because in cutting squares of glass there is a very great waste, and more time is expended than if the window had been of a rectangular form.

PAINTING,

As applied to purposes of building, is the application of artificial colours, compounded either with oil or water, in embellishing and preserving wood, &c.

This branch of painting is termed *economical*, and applies more immediately to the power which oil and varnishes possess, of preventing the action of the atmosphere upon wood, iron, and stucco, by interposing an artificial surface; but it is here intended to use the term more generally, in allusion to the decorative part, and as it is employed by the architect, throughout every part of his work, both externally and internally.

In every branch of painting in oil, the general processes are very similar, or with such variations only, as readily occur to the workman.

The first coatings, or layers, if on wood or iron, ought always to be of ceruse or white-lead, of the best quality, previously ground very fine in nut or linseed oil, either over a stone with a muller, or, as that mode is too tedious for large quantities, passed through a mill. If used on shutters, doors, or wainscottings, made of fir or deal, it is very requisite to destroy the effects of the knots, which are generally so completely saturated with turpentine, as to render it, perhaps, one of the most difficult processes in this business. The best mode, in common cases, is, to pass a brush over the knots, with ceruse ground in water, bound by a size made of parchment or glue; when that is dry, paint the knots with white-lead ground in oil, to which add some powerful siccative, or dryer, as red-lead, or litharge of

lead; about one-fourth part of the latter. These must be laid very smoothly in the direction of the grain of the wood.

When the last coat is dry, smooth it with pumice-stone, or give it the first coat of paint, prepared or diluted with nut or linseed oil; after which, when sufficiently dry, all the nail-holes or other irregularities on the surface must be carefully stopped with a composition of oil and Spanish white, commonly known by the name of putty. The work must then be again painted with white-lead and oil, somewhat diluted with the essence of oil of turpentine, which process should, if the work be intended to be left of a plain white, or stone-colour, be repeated not less than three or four times; and if of the latter colour, a small quantity of ivory or lamp-black should be added. But if the work is to be finished of any other colour, either grey, green, &c. it will be requisite to provide for such colour, after the third operation, particularly if it is to be finished flat, or, as the painters style it, dead-white, grey, fawn, &c. In order to finish the work flatted or dead, which is a mode much to be preferred for all superior works, not only for its appearance, but also for preserving the colour and purity of the tint, one coat of the flatted colour, or colour mixed up with a considerable quantity of turpentine, will be found sufficient; although in large surfaces it will frequently be requisite to give two coats of the flatting colour, to make it quite complete. Indeed, on stucco, it will be almost a general rule.

In all the foregoing operations, it must be observed that some sort of dryer is absolutely requisite; a very general and useful one is made by grinding in linseed, or, perhaps, prepared oils boiled are better, about two parts of the best white copperas, which must be well dried with one part of litharge of lead: the quantity to be added will much depend on the dryness or humidity of the atmosphere, at the time of painting, as well as the local situation of the building. It may here be noticed, that there is a sort of copperas made in England, and said to be used for some purposes in medicine, that not only does *not* assist the operation of drying in the colours, but absolutely prevents those colours drying, which would otherwise have done so in the absence of this copperas.

The best dryer for all fine whites, and other delicate tints, is sugar of lead, ground in nut-oil, but being very active, a small quantity, about the size of a walnut, will be sufficient for twenty pounds of colour, when the basis is white-lead.

It will be always necessary to caution painters to keep their utensils, brushes, &c. very clean, as the colour would otherwise soon become very foul, so as to destroy the surface of the work. If this should happen, the colour must be passed through a fine sieve, or canvass, and the surface of the work be carefully rubbed down with sand-paper or pumice-stone; the latter should be ground in water, if the paint be tender, or recently laid on. The above may suffice as to painting on wood, either on inside or outside work, the former being seldom finished otherwise than in oil: four or five coats are generally sufficient.

It does not appear that painting in oil can be serviceable in stucco, unless the walls have been erected a sufficient time to permit the mass of brick-work to have acquired a sufficient degree of dryness. When stucco is on battened work, it may be painted over much sooner than when prepared on brick. Indeed, the greatest part of the art of painting stucco, so as to stand or wear well, consists in attending to these observations, for whoever has observed the expensive power of water, not only in congelation, but also in evaporation, must be well aware that when it meets with any foreign body, obstructing its escape, as oil painting, for instance, it immediately resists it, forming a number of vesicles or particles, containing an acrid lime-water, which forces off the layers of plaster, and frequently causes large defective patches, not easily to be eradicated.

Perhaps, in general cases, where persons are building on their own estates, or for themselves, two or three years are not too long to suffer the stucco to remain unpainted, though frequently, in speculative works, as many weeks are scarcely allow to pass.

The foregoing precautions being attended to, there can be no better mode adopted for priming, or laying on the first coat on stucco, than by linseed or nut-oil, boiled with dryers, as before mentioned; taking care, in all cases, not to lay on too much, so as to render the surface rough and irregular, and not more than the stucco will absorb. It should then be covered with three or four coats of white-lead, prepared as described for painting on wainscotting, allowing each coat a sufficient time to dry hard. If time will permit, two or three days between each layer will be advantageous. When the stucco is intended to be finished in any given tint, as grey, light green, &c. it will then be proper, about the third coat of painting, to prepare the ground for such tint, by a slight advance towards it. Grey is made with white-lead, Prus-

sian-blue, ivory-black, and lake; sage-green, pea, and sea-greens, with white, Prussian-blue, and fine yellows; apricot and peach, with lake, white, and Chinese vermilion; fine yellow fawn colour with burnt terra sienna, or umber and white; and olive-greens with fined Prussian-blues, and Oxfordshire ochre.

Distemper, or painting in water-colours, mixed with size, stucco, or plaster, which is intended to be painted in oil when finished, but not being sufficiently dry to receive that oil, may have a coating in water-colours, of any given tint required, in order to give a more finished appearance to that part of the building. Straw-colours may be made with French whites and ceruse, or white-lead and masticot, or Dutch pink. Greys, full, with some whites and refiner's verditer. An inferior gray may be made with blue-black, or bone-black and indigo. Pea-greens with French green, Olympian green, &c. Fawn-colour with burnt terra de sienna, or burnt umber and white, and so of any intermediate tint. The colours should all be ground very fine, and mixed with whiting and a size made with parchment, or some similar substance. Less than two coats will not be sufficient to cover the plaster, and bear out with an uniform appearance. It must be recollected, that when the stucco is sufficiently dry, and it is desirable to have it painted in oil, the whole of the water-colours ought to be removed, which may easily be done by washing, and when quite dry, proceed with it after the direction given on oil-painting in stucco.

If old plastering has become disfigured by stains, or other blemishes, and it be desired to have it painted in distemper, it is, in this case, advisable to give the old plastering, when properly cleaned off and prepared, one coat, at least, of white-lead ground in oil, and used with spirits of turpentine, which will generally fix old stains; and when quite dry, take water-colours very kindly.

MENSURATION OF PAINTERS' WORK.

Painters' work is measured by the yard square, and the dimensions are taken in feet, inches, and tenths. Every part which the brush has passed over is measured, consequently the dimensions must be taken with a line that girts over the mouldings, breaks, &c. All kinds of ornamental work produces an extra price, according to the nature of the imitations, &c. Carved work is also valued according to the time taken in painting it.

RAIL-ROADS

AND

LOCOMOTIVE ENGINES.

Amidst the various speculations of the day, perhaps none have more deservedly excited the public interest than that of the numerous projected lines of rail-road for diminishing the friction of carriages, and for propelling carriages on them by either gas or steam-power.

The lessening the friction produces a consequent diminution in the power which otherwise would be required to propel a given weight; and therefore, is, in a commercial nation, like that of the united kingdom, a subject worthy of the highest consideration.

Railways were originally made of wood, and appear to have been first introduced between the river Tyne and some of the principal coal-pits, as early as the year 1680. The scarcity of this material, and the expense of frequent repairs, soon suggested an idea that iron might be more advantageously employed. At first, flat rods of bar-iron were nailed upon the original wooden rails, or, as they were technically called, *sleepers;* which, though an expensive process, was found to be a great improvement. But as the wood on which these rested was liable to rot and give way, these railings were soon after superseded by others made entirely of iron.

These *tram* or *rail-roads* have, for a considerable length of time, been much used in the colliery and mining districts; and some few have been carried from one town or manufacturing district to another. The principal of these latter in England and Wales are, the Cardiff and Merthyr, 26¾ miles long, running near the Glamorganshire canal; the Caermarthen; the Lexhowry, 28 miles, in the counties of Monmouth and Brecknock; the Surrey 26 miles; the Swansea, 7½ miles; one between Gloucester and Cheltenham; besides several in the north of England.

Railways are of two kinds, arising from the disposition of

the flanch that is to guide the wheels of the carriage, and prevent it from running off the rail. In the one, the flanch is at right angles, and of one piece with the flat surface of the rail: in the other, the flat surface of the rail is raised above the level of the ground, and the flanch is fixed on the wheel of the carriage, at right angles to the tyre, or iron placed on the circumference of the wheel, to strengthen it. Besides these, another kind of railway has lately been introduced by Mr Palmer, which consists of a single rail, supported some height from the surface of the ground: on this, two wheels confined in sufficient frame-work, are placed, suspending the load equally balanced on either side. This arrangement certainly seems to ensure the grand principle of lessening friction, and doubtless will, in many situations, be found a great improvement.

Previously to entering upon the probable advantages likely to result from a general introduction of railways, we shall give the substance of the specification of a patent, obtained in Sept. 1816, by Messrs Losh and Stephenson, both of whom are well known to those interested in the subject.

These gentlemen preface a description of their method of facilitating carriages along tram and railways, with an observation, that there are two kinds of railways in general use; the one consisting of bars of cast-iron, generally of the shape of that described by *a*, fig. 631, the other of the shape of that described by figs. 630 and 631. That shown at *a*, fig. 629, is known in different situations by the denomination of the edge rail, round-top rail, fish-backed rail, &c. That shown at figs. 632 and 633, by the denomination of the plate-rail, tram-way plate, barrow-way plate, &c. The first we shall distinguish by the name of the edge railway; the second, by that of the plate railway.

In the construction of edge railways, Messrs Losh and Stephenson's objects are, first, to fix both the ends of the rails, or separate pieces, of which the ways are formed, immovable, in or upon the chairs or props by which they are supported, secondly, to place them in such a manner, that the end of any one rail shall not project above or fall below the correspondent end of that with which it is in contact, or with which it is joined; thirdly, to form the joinings of the rails, with the pedestals or props which support them, in such a manner, that if these props should vary from their perpendicular position in the line of the way, (which in other railways is often the case,) the joinings of the rails with each other would remain as before such varia-

tion, and so that the rails shall bear upon the props as firmly as before. The formation of the rails or plates of which a plate railway consists, being different from the rails of which the edge railways are composed, they are obliged to adopt a different manner of joining them, both with each other, and with the props and sleepers on which they rest. But in the joining these rails or plates upon their chairs and sleepers, they fix them down immovably, and in such a manner that the end of one rail or plate does not project above, or fall below the end of the adjoining plate, so as to present an obstacle, or cause a shock to the wheels of the carriages which pass over them, and they also form the joinings of these rails or plates in such a manner as to prevent the possibility of the nails, which are employed in fixing them in their chairs, from starting out of their places from the vibration of the plates, or from other causes.

In what relates to the locomotive engines and their carriages, which may be employed for conveying goods or materials along edge railways or plate railways, or for propelling or drawing after them the carriages or wagons employed for that purpose, their invention consists in sustaining the weight, or a proportion of the weight, of the engine, upon pistons, movable within cylinders, into which the steam or the water of the boiler is allowed to enter, in order to press upon such pistons; and which pistons are, by the intervention of certain levers and connecting rods, or by any other effective contrivance, made to bear upon the axles of the wheels of the carriage upon which the engine rests. In the formation of the wheels it is their object to construct them in such a manner, and to form them of such materials, as shall make them more durable and less expensive in the repairs than those hitherto in use. This is accomplished by forming the wheels either with spokes of malleable iron, and with cast-iron rims, or by making the wheels and spokes of cast-iron, with hoops, tyres, or trods, of malleable iron, and in some instances, particularly for wheels of very small diameters, instead of spokes of malleable iron, employing plates of malleable iron, to form the junction between the naves and the cast-iron rims of the wheels.

The advantages gained by this method of constructing railways are, first, that the separate pieces of which they consist are, *cæteris paribus*, rendered by this mode of joining them, capable of sustaining a much heavier pressure than those which are joined in the usual way. Secondly, by this

mode of joining the rails, they remove the liability to which rails joined in the usual plan (where the end of one rail is seldom in the same plane with the correspondent end of the next,) are exposed, of receiving blows and shocks from the carriages which move over them, and to which blows and shocks the great breakage which often occurs in railways, when not made of enormous weight, may generally be referred; and as action and reaction are mutual and contrary, if they prevent the communication of shocks to the rails, they at the same time preserve the wheels, the carriages, and engines which move over them, from the reaction which is often destructive to them. As the centre of gravity in a loaded coal-wagon is, from its shape, much elevated, there is generally a great waste of coal from the shaking of the wagons, to which that circumstance, (the position of the centre of gravity,) makes them more liable when they encounter obstacles, as they do at the junction of almost every two rails on the common railways. On Losh and Stephenson's railways, the loss thus arising is, if not entirely prevented, at least considerably diminished, by the steady and regular motion of the wagons. The usual method of fixing down the plates, of which the plate railways employed in coal-mines, and there called tram and rolley-ways, are formed, is by a single nail, nearly at each end of each plate; which nail passes through a hole in the plate, and fixes it to a sleeper of wood. These nails, from the vibration of the plate, or the motion of the sleeper, or some other cause, generally very soon start up, and consequently the plates work loose, and very frequently the nails come entirely out. The delay of work, the breakage of plates, wheels, &c. and the injury which the horses receive from the loose nails which result from the mode of fixin the plate railways, are generally complained of, and therefore the advantages of a plan which will remove these inconveniences must be apparent.

When locomotive steam-engines are employed as the moving or propelling power on railways, these gentlemen have, from much practice, found it of the utmost importance, that they should move steadily, and as free as possible from shocks or vibrations, which have the effect of deranging the working parts of the machinery, and lessening their power. It is therefore to produce that steadiness of motion, and to prevent the engines from receiving shocks, and to preserve their equilibrium, that they employ the floating pistons, which, acting on an elastic fluid, produce

the desired effect with much more accuracy than could be obtained by employing the finest springs of steel to suspend the engine. The wheels which are constructed on this plan will be found, when compared with those already in use, (the weights of both being equal,) to be more durable; for the arms, when made of malleable iron, being infinitely less liable to be broken by shocks or concussions than those of cast-iron, may be of less weight, and in fewer numbers, so that the excess of weight of the extra arms of the cast-iron wheels may be applied on the rims of these wheels, and thus add to the substance of that part which alone suffers from the friction of the rails. The rims of wheels thus constructed, can also be case-hardened without risk of breaking, either in cooling or afterwards, which is not the case when wheels are cast in one piece. The advantage of hooping cast-iron wheels with malleable iron tyres or trods, is, that when such tyres or trods are worn through, they can very easily be replaced at a small expense, and that the tyre, which is not liable to break, receiving the shocks from the re-action of the rails, preserves the cast-iron wheel, by considerably lessening the effect of such shocks on the cast metal.

As it is perhaps impossible to cast the bars or plates of metal of which railways and plate-ways are composed perfectly straight, and correctly even and smooth on their surfaces, and equally difficult to fit the joints with mathematical accuracy, the wheels of the engines and wagons will always have some inequalities and obstacles to encounter. From these circumstances, therefore, Messrs Losh and Stephenson are induced to employ the improvements which they have made in the construction of the locomotive engine, and in the wheels of carriages upon edge railways and plate railways, constructed according to their own plans; but it is apparent that their adoption on the rail and plate-ways on the usual construction, is of still more importance.

They therefore claim as a method of facilitating the conveyance of goods, and all manner of materials along edge railways or plate railways, the use of any of the plans they have described singly, as well as the whole of them collectively. They have no hesitation in saying, that on a railway constructed on their plan, and with a locomotive engine and carriage-wheels on their principle, the expedition with which goods can be conveyed with safety, will be increased to nearly double the rate with which they are

at present usually taken along railways, and with less interruption from the breakage of wheels, rails, &c. than at present occurs, and with much less injury to the working parts of the engine.

In order that their specification may be more clearly understood, we have annexed a schedule of drawings.

Fig. 629 represents a longitudinal view of the locomotive engine on the edge railway. *a a a*, are the cylinders containing the floating pistons *b b*, which are more fully described in the next figure.

Fig. 630 represents a cross section of fig. 629, at the middle cylinders *a, a*; *b b* are the floating pistons connected with the wrought iron rods *c c*, the ends of which rest upon the bearing brasses of the axles of the wheels *d d*. These pistons press equally on all the axles, and cause each of the wheels to press with an equal stress upon the rails, and to act upon them with an equal degree of friction, although the rails should not all be in the same plane, for the bearing brasses have the liberty of moving in a perpendicular direction in a groove or slide, and, carrying the axles and wheels along with them, force the wheels to accommodate themselves to the inequalities of the railway.

Fig. 634, is a view of the wheel, with wrought iron arms. *a a a a a a* show how the arms are cast in the nave *b b*, and dropped into the mortise-holes *c c c c c c* in the rim, which are dovetailed, to suit the dovetailed ends of the arms *d d d d d d*. The arms are heated red hot previously to dropping them into the holes, in order to cause them to extend sufficiently for that purpose, for when cold they are too short. In doing this they take advantage of that quality which iron possesses of expanding on the application of heat, and of contracting again to its former dimensions on cooling down to the same temperature from which it was raised; the arms, therefore, on cooling, are drawn with a force sufficient to produce a degree of combination between their dovetailed ends and the mortises of the rim, which prevents the possibility of their working loose; they are afterwards keyed up; the mortise-holes are also dovetailed, from the tail side of the wheel, (*a a*, fig. 635,) to the crease side, (*b b*, on the same figure.)

Fig. 635, is a cross section through the centre of the wheel, with wrought iron arms.

Fig. 636 is an end view of fig. 635.

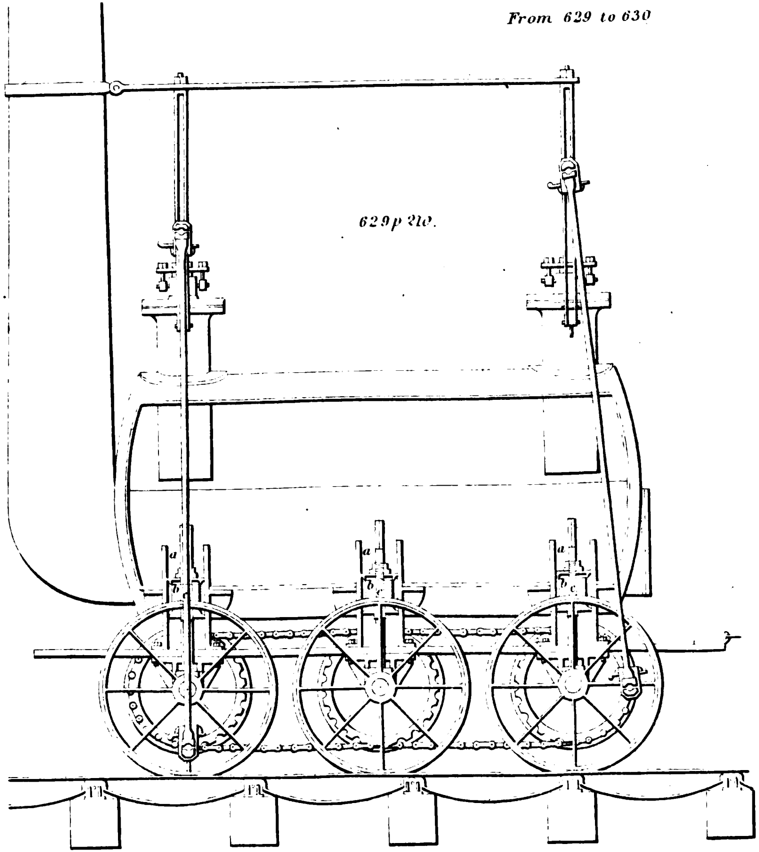
Fig. 637 represents a view of their edge railway; showing a rail *a*, connected with the two adjoining rails, the ends of which are shown by *b b*, and also with the props or pedestals on which they rest. *d d* show the metal chairs, and *c c* the stone supports. The joints *e e* are made by the ends of the rails being applied to each other by what is denominated a half-lap, and the pin or bolt *g*, which fixes them to each other, and to the chair in which they are inserted, is made to fit exactly a hole which is drilled through the chair, and both ends of the rails at such a height as to allow both ends of the rails to bear on the chair, and the bearance being the apex of a curve, they both bear at the same point. Thus the end of one rail cannot rise above that of the adjoining one; for although the chair may move on the pin in the direction of the line of the road, yet the rails will still rest upon the curved surface of their bearance without moving.

Fig. 638 is a cross section of their edge railway through the middle of one of the chairs *a*, and across the ends of the two adjoining rails *c d* and the pin *e*; *f* is the stone support or sleeper.

LOCOMOTIVE ENGINE

Pl 93

From 629 to 630



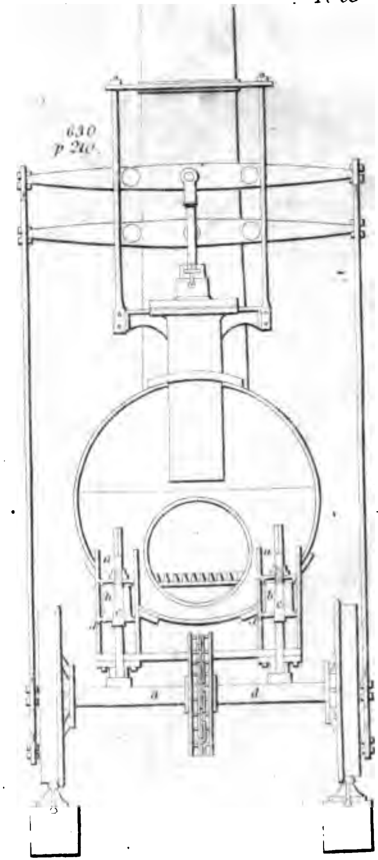


Fig. 639 is a cross section of a rail *a*, at the centre, and shows the carriage *c* behind.

Fig. 640 is a plan of the railway described at fig. 637, showing the half-lap joinings of the rails *c c*, placed in their carriages *d d*.

Fig. 641 is a view of the cast-iron wheel with the malleable iron tyre. This wheel is made with curved spokes, as shown at *a a a a a a a a a a*, in the figure, and with a slit or aperture in the rim, shown at *b*, into which a key is inserted. The reason of this is, that on the application of the hot tyre the cast metal expands unequally, and the rim is liable to be cracked, and the arms drawn off, unless the first is previously slit or opened, and the latter curved, which allows them to accommodate themselves to the increased diameter of the wheel; by this formation of the wheel the tyre might be forced on when cold, and keyed up afterwards.

Fig 642 is a cross section of fig. 641, through the centre. *a a* show the tyre, *b b b b* show the metal rim. This cast metal rim is dovetailed; so that when the tyre, which is dovetailed to suit it, is put on hot, it contracts and applies itself to the rim with a degree of adhesion which prevents its coming off from the motion of the wheel on the railway. This wheel is of the form to suit an edge railway, and make it answer for a plate rail it only requires the rim to be round or flat.

Fig. 643 is an end view of fig. 641, without the malleable iron tyre.

Fig. 644 represents a view of a rolley or tram-wheel, calculated to move upon a plate railway. *a a a a* show the malleable iron arms, fastened to the projections *b b b b*, on the inside of the rim *c c c*, by the bolts *d d d d*.

Fig. 645 is a cross section of fig. 644, through the centre of the wheel. *a a* show the arms, *c c* the rim, *d d* the bolts.

Fig. 646 represents a view of a rolley or tram-wheel, with a plate of malleable iron *a a a a*, to form the junction between the nave *b b* and the cast metal rim *c c c c*.

Fig. 647 is a cross section of fig. 646. *a a* show the plate upon which the nave *b b* is cast. *c c* show the cast-iron rim which is cast upon the plate, the edges of which plate are previously covered with a thin coating of loam and charcoal dust, or other fit substance, to prevent the too intimate adhesion between the iron plate and metal rim, so that if the rim should break, it can easily be taken off and replaced by casting another on the plate.

Fig. 648 represents the plate railway on their plan. At the end of each plate are projections *a a a a*, to fit into the dovetail carriage *b b*, and at each end of each plate are projections or tenons *c c c c*, which fall into the mortise-hole, (*d*, in figs. 649 and 650,) in the carriage *b b*, and secure the rail from an end motion; and when the pin or key *e* is driven into its place, it secures the plates from rising, thus they are fixed immovable in their carriages.

Fig. 649 is a front view of fig. 648.

Fig. 650 is a plan of the carriage, in which *a a* show the nail holes through which the nails are driven to secure it to the sleeper. When the rails are laid in this carriage, and secured by the pin or key, they keep these nails from starting up by resting upon them.

Fig. 651 is a cross section of the carriage, and the end of one of the plate rails.

Fig 629* shows a rail of the common way, inclining out of the horizontal position, as they very often do from the yielding of the props or pedestals, and of course a shock is sustained by the wagons in passing the joining to the next rail.

The ease with which cast-iron can be made into any required shape has, till very recently, given to rails of that material a decided superiority over those of malleable iron. But the brittleness of the former renders such rails very liable to be broken, unless, indeed, they be of such substance as will resist the effects of the blows or shocks to which they are exposed, and which will require them to be of considerably greater weight than otherwise would be necessary. To obviate this, numerous experiments have been made with a view to substitute malleable iron for cast-iron rails.

Rails of malleable iron appear to have been first used at Lord Carlisle's works, at Tindall Fell, in Cumberland, about the year 1808; and though found there, and also at two or three other places at which they were tried, to be a saving in the first cost, and much less liable to accident, they have not till very lately been much used. In fact, it was not till some time after Mr Birkinshaw, of the Bedlington Iron Works, had obtained a patent for malleable iron rails of a new and improved construction, that rails of this material came into competition with the cast-iron rails.

The form of the malleable iron rails previously to this was that of a parallelopipedon; which was liable to two objections, either that the narrowness of the surfaces, when compared to the breadth of the rim of the carriage wheel, was so considerable as to expose both the wheel and the rail to great injury from wear; or, if the breadth of the rail was increased to remove this objection, the weight of the rail would make the cost amount to almost a prohibition of its use.

Mr Birkinshaw obtained his patent in October 1820; and the improvement consisted in making the rails in the form of prisms, though their sides need not of necessity be flat. The upper surface, on which the wheel of the carriage is to run, is slightly convex, in order to reduce the friction; and the under part, which rests on the supporting blocks, chains, rests, standards, or pedestals, is mounted upon the sleeper. The wedge form is proposed, because the strength of the rail is always in proportion to the square of its breadth and depth. Hence this form possesses all the strength of a cube equal to its square, with only half the quantity of metal, and consequently half the cost of the former rail. Sufficient strength, however, may be still retained, and the weight of metal further reduced, by forming the bars with concave

From 629* to 645

631 629 * p 211.

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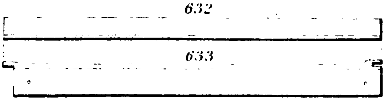

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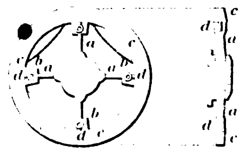

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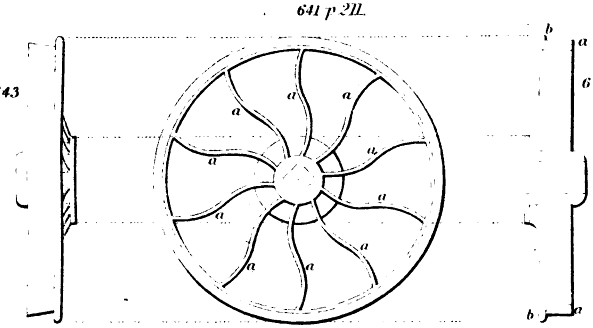

634 p 210.

636 635

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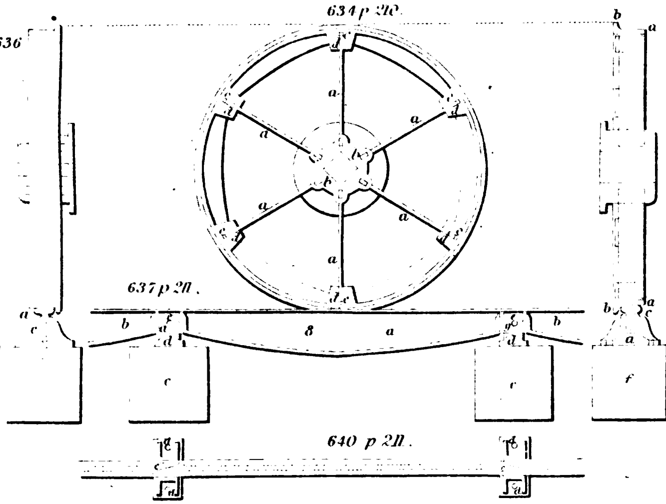
639 p 211. 638

640 p 211.



sides, which is the form of rail the patentee decidedly prefers, although the prism or wedge form, in all its varieties, is the principle upon which his patent-right is founded.

The mode of making these wedge-formed rails of malleable iron is, by passing bars of iron, when heated, through rollers, having grooves or indentations cut upon their peripheries, agreeably to the intended shape of the bar to be produced. But, though the patentee recommends, and adopts this mode as the most eligible means of producing these rails, he claims the exclusive right of manufacturing and rendering the wedge-formed bars or rails of any length, for the purpose of forming or constructing rail-roads.

The advantages derived from this method of constructing railways may be as follows:

1st. The original cost of a malleable iron railway is less than a cast-iron railway of equal strength.

2dly. As the rails can be made in the lengths of 9, 12, 15, or 18 feet each, and even longer when required, the number of joints is hereby reduced; and thus is removed, in a great measure, the liability to which the short rails now in use are exposed, of receiving blows and shocks from the carriages which move over them.

3dly. In order to remedy the evil arising from the rails being imperfectly joined, the plan of welding the ends together has been adopted; by this means making one continued rail the whole length of the road without any joint whatever.

4thly. It hence follows, that on iron railways, the loss of coals, occasioned by the jolting of the wagons at the joints of the rails, and the injury done to the wheels, the carriages, and engines from the same cause, are, if not entirely prevented, at least considerably diminished.

In September 1821, Mr Losh took out another patent for further improvements in the construction of railways. These improvements consist, first, in fixing bars of malleable iron on the upper surface of a line of cast or malleable iron rails, of whatever form such rails may be, in the longitudinal direction of the rails when laid, so as to form an uninterrupted line the whole length of the bar, which may be as long as it shall be found convenient, and of the same breadth, or a little broader or narrower than the upper surface of the rails to which it is fixed. Secondly, in fixing, in some cases, a band or strap of malleable iron to the under surface of cast-iron rails, in order that such strap or band may, by its power of tension, give support to the cohesion of the parts of cast-

iron rails, and admit of its being made lighter, of less expense, and less liable to breakage. Thirdly, in forming a rail, by fixing two bars of malleable iron on their sides or edges, and fixing them in that position by bolts and studs, or any other convenient method; and in placing and fixing on their upper edges a flat bar of malleable iron, or one which is slightly curved or rounded at the edges to diminish friction, so that the bar or plate, placed and fixed on the upper edges of the two malleable iron bars, shall form the surface upon which the wheels of the carriage are to revolve.

Mr Losh states, in the specification of his patent, that rail-roads are now become so general, that for the information of mechanical men, or those who have the direction of constructing and laying them, drawings would be quite superfluous; he therefore proceeds to state the methods which he has found the most convenient for forming the junction of the plate or flat bar, which he applies upon the surface of the body of the rail; and also the mode by which he attaches the band or strap to the lower edge of the cast-iron rail.

He recommends the dimensions of the bars meant to form the upper surface of a railway, calculated to carry locomotive engines of seven or eight tons, and wagons of three or four tons weight each, to be fifteen or sixteen feet long, two and a quarter inches broad, and half to five-eighths of an inch thick. At every eighteen inches or two feet of the length of this surface-plate, a tenon is firmly welded or riveted, or otherwise attached to the under side, taking care in this operation to leave the upper surface of the plate even as before. These tenons have holes through them in the transverse direction of the bars, to take a pin or rivet of from about a quarter to half an inch in diameter; and at each extremity of the plate a tenon is fixed on by welding, having previously cut off a piece of about two inches long, and of half the breadth of the bar, from the opposite ends of the bar or plate, and at the opposite angles, so that when two bars, so prepared, are brought to join at the ends, the joint is what is denominated a half-lap, or scarfed joint.

If it be required to place malleable iron plates or bars on cast-iron rails, nothing more is necessary than to make the rails with mortise-holes, to receive the tenons with transverse holes, to correspond with those in the tenons fixed on the plates; and, after placing the rails in their chairs or carriages, to apply the plate to the surface of the rails, and

to drop the tenons into the mortise-holes, and to secure them there by a pin driven tightly into and through the transverse holes of the tenons and mortise-holes. The mortise-holes are made in the rails by placing a core in the mould previously to running in the metal, and lest this core should weaken the rail, it is advisable to add as much metal on the outside of the rail, in the form of a boss, where the hole is, as will make up the deficiency. A chair is then placed on a pedestal at every three or four feet distance, less or more, according to the length of the cast-iron rails; and each of these must be supported at its ends : these rails are generally made with half-lap joints, and to rest on a curb bearance. Care is taken that where the ends of the surface-plates meet to form a joint, they shall be sustained by a chair; and the reason for making the joints half-lapped, or scarfed, with tenons welded to these half-laps is, that one pin or bolt will secure both the adjoining ends of the surface-plates, and of the bars of cast-iron, more perfectly in the chair, than any other known contrivance, when the bearance is the apex of a curve. Surface-plates thus prepared with tenons, as described above, may be attached and fixed to the upper surface of a series of malleable iron rails placed in chairs, which rails consists of flat bars, (generally three or four feet long, more or less, but sometimes also as long as the surface plate,) fixed on their thin edges, so as to present the greatest resistance to a weight bearing upon them. For this purpose, pins or rivets may be driven through the transverse holes in the tenons on the surface-plate, and the corresponding transverse holes made in the supporting bars; and thus may be formed a cheap and very serviceable railway. In this case, the supporting bars should not be less than two and a half inches deep, by half an inch thick, if meant to carry locomotive engines. For smaller carriages, the bars may be of less dimensions, in proportion to the decreased weight of the carriages.

In forming the rail, consisting of a plate of malleable iron, supported by two flat bars of the same material, Mr Losh prepares the surface-plate as above with tenons, and having fixed the two bars intended to support it on their edges, parallel to each other, in a series of chairs, and secured them in that position by bolts passing through them, and by intervening studs, to keep them at a proper distance, which is such, that the sides or edges of the surface-plate, which may be a little curved or rounded, to diminish the friction from the wheels passing over it, shall project about

a quarter of an inch beyond them. By these intervening studs, the surface-plate is laid upon them, and the tenons are dropped in between them, and fixed by pins or bolts passing in a transverse direction through holes in the bars, which are made to correspond with holes in the tenons, and thus securing them as if they were in mortise-holes. The strap or band of malleable iron is fixed by Mr Losh to the under edge of the cast-iron rail, by perforating both ends of the strap, near the extremities, with a long hole, calculated to pass over studs of malleable iron, which are fixed at each end of the rail, by being run at the time of casting the rail or otherwise. The studs should be about one and a half inches broad, by three-eighths of an inch thick, and placed so, that when the strap has been put over them in a heated state, it cannot, in contracting, slip its hold; but will, on the contrary, fix itself the closer. These straps are made of malleable iron bars, about one and a half inches broad, three-eighths to half an inch thick, and of such length as to draw strongly against the studs and bottom of the rail, when in its position. The under edge of the cast-iron rail to which this strap is applied being curved, it will, when the strap is fixed upon the studs, by an extension of its length by heat, apply itself firmly to, and support every part of the lower edge of the rail, in contracting, by parting with its heat; and till the power of tension of this strap is overcome, and it extends its length, or the studs break, the rail cannot give way.

Many other methods, perhaps equally secure, may be made use of to place and fix surface-plates on the surface of rails; but Mr Losh prefers the plan pointed out, by tenons and mortise-holes, and by rivets passed through holes in such tenons, and through corresponding holes in the supporting bars; because, when worn or damaged, these plates can easily be taken off and replaced, without injury to that part of the rail which supports them.

The principal patents obtained before the above described, are those by Blenkinsop, Brunton, and Chapman; specifications and drawings of which may be seen in the Repertory of Arts.

Mr Blenkinsop's patent was obtained the 10th of April 1811, and is for a method of fixing into the ground a toothed rack, or longitudinal piece of cast-iron, or other fit material, having teeth, or protuberances, into which a toothed or cogged wheel, connected with a locomotive carriage, plays.

Mr Brunton's patent was taken out the 22nd of May 1813, and is for a method of propelling machines along a railway by means of two or more bars or legs, which, by receiving a reciprocating motion from a steam-engine, act against the ground like a man's legs, when in the act of walking. These bars or legs are constructed of metal or wood, and of such length that, during the act of propulsion, the angle formed by the said bars or legs and the surface of the road may be such, as to afford sufficient resistance from the materials propelled against to overcome the friction of the body to be moved. This angle admits of considerable latitude, but will be found to answer best when between 50 and 70 degrees.

The reader has now been informed of the principal patents that have been taken out for improvements in rail-roads. The rails most in use are those of cast-iron by Losh and Stephenson, and of malleable iron by Birkinshaw.

Previously to constructing a railway, it is necessary to ascertain, as accurately as the nature of the thing will admit, the quantity of lading expected to traverse each way upon its line. For if the weight of the carriage of merchandize, &c. be more in the one direction than in the other, as will frequently be the case in forming a line of railway from a manufacturing or mining district to a town, the railway must have a gentle inclination or descent; but if the lading is expected to be nearly equal in both directions, with a preponderance at certain periods only, the railing must, in such case, be set out in levels, or in lines nearly level, and the ascents and descents made by planes inclined accordingly.

That the reader may see the necessity of paying due attention to this point, we shall show the advantages that will result from constructing railways with a gentle gradual descent, when the carriage of the articles of trade are considerably more in one direction than the other.

Dr Armstrong, in his Recreations in Agriculture, observes, that a horse travelling at the usual rate that wagons move, would, with ease, under favourable circumstances, draw 20 tons: but Mr Fulton says, that five tons to a horse is the average work on railways, descending at the rate of three miles per hour; or one ton upwards with the same speed. Mr Telford, an experienced engineer, observes, that on a railway well constructed, and laid with a declivity of 50 feet in a mile, one horse will readily take down wagons containing 12 to 15 tons; and bring back the same wagons with four tons in them. Mr Joseph Wilkes, in

1799, stated that a horse of the value of 20*l.* drew down the declivity of an iron road, $\frac{5}{16}$ths of an inch in a yard, 21 carriages or wagons, laden with coals and timber, weighing 35 tons, overcoming the *vis inertiæ* repeatedly with ease. The same horse, up this declivity, drew five tons with ease. On a different railway, one horse, value 30*l.* drew 21 wagons of five cwt. each, which, with their loading of coals, amounted to 43 tons 8 cwt., down the declivity of 1-3d of an inch in a yard; and up the same place he afterwards drew seven tons; the cwt. in all these experiments by Mr W. being 120 lbs.

Though in the preceding statements there is an apparent variance, the authors are not the less entitled to credit; because the variations may have arisen from difference in the physical strength of the animals, or in the method of constructing the railways. To make the case, however, as clear as possible, we shall here present our readers with some observations and calculations deduced from known data, which have lately appeared in a very able pamphlet, entitled "A Report on Rail-Roads and Locomotive Engines," by Mr Charles Sylvester, civil engineer.

Mr Sylvester, having made some judicious observations on the principles of railways, and the nature of the friction to be overcome, states, that, "agreeably to the principles laid down in the commencement, when a force is applied equal to the friction, the smallest force above that would, if continued, generate any required velocity. But it will be desirable to have such a force at command as will generate the necessary velocity in a short time, and when that has been accomplished, to reduce this force, but still to leave it fully equal to the friction. If any part of the route has an inclination, there ought to be an extra force at command, above what would be required for a dead level. The plane on which this experiment was made, inclined, in the direction of the load, about $\frac{1}{9}$ of an inch to a yard. This is as great, or perhaps a greater inclination than any rail-road ought to have, where loaded carriages go up and down. The moving force ought, therefore, to be always greater than the friction added to the force which is required to overcome the inclination of the plane. The latter force assists the body to go down, and equally resists it in moving upwards.

"On this account," says he, "I have used, or supposed, a moving force, which will give the velocity of 5 miles an hour, or $7\frac{1}{3}$ feet per second, in the space of one minute. This will be performed down the above plane by the engine making

45 strokes per minute, (the circumference of the wheel being nine feet,) with a pressure of 9.7 lbs. upon an inch, of each of the two cylinders, the area of each being 63.6 square inches. The weight of the engine and 16 wagons is equal to 154,560 lbs. or nearly 70 tons. The velocity of five miles an hour being acquired after one minute, the only force to keep the whole in motion, at the same rate, will be the difference between the gravity of the weight down the plane and the friction. The friction is 900 lbs.; the gravitating force of the weights down the plane 540 lbs.; therefore 900 — 540 = 360 lbs.

"If the same weight, at that speed, had to move on a dead level, and acquired the same velocity in one minute as before, the moving force would require to be 1781 lbs. which would require a pressure of 13.7 lbs. upon one inch. But after the speed is obtained, it will require only 7 lbs. to keep it moving at the same rate. If the same load were required to move up the plane, it would require a moving force of 2328 lbs. or a pressure upon every square inch of 18.3 lbs. And this velocity would be kept up by a constant pressure of 1447 lbs. which will be 11.3 lbs. upon every inch of the piston.

"In starting the engine, in the first instance, and giving the required velocity, it is probable the effects will agree very nearly with these calculations; namely, 154,560 lbs. moved at the rate of five miles an hour, with a pressure of 9.7 lbs. upon every inch of the piston. Whether the pressure were reduced to the difference between the friction and the force upon the plane, which is calculated at 2.8 lbs. it is difficult to say, as there was no steam-gauge to indicate the pressure when the engine was going."

In table 1, at a more advanced part of the work, Mr Sylvester states, that, when the engine is required to travel at the rate of nine miles per hour, the force necessary to overcome the weight, 154,560 lbs. will be for the first minute, when the engine is travelling on a level 2890.81 lbs.; when moving down the plane 2461.61 lbs., and when moving up the plane 3320.01 lbs. But that, when the velocity is attained, a force that will balance the friction is sufficient to keep up the required velocity. This force is, for travelling on a level, 900 lbs.; for moving down the plane, 471 lbs.; and for moving up the plane 1329 lbs.

By this, therefore, it is evident that, when the lading is expected to be considerably more in one direction of the line of rail-road than it is in the other, the advantage which

will arise from making the road with a gentle slope, is very great. This kind of railing is also preferable when the lading is only equal at certain periods. For then the expense of extra horses, to draw the additional weights up the plane during these periods, will fall infinitely short of the expense saved by making the plane with a gentle inclination.

The necessary preliminaries being settled, the engineer will obtain much greater facility, as also a diminution of expense, by beginning to lay down the rails on any part of the intended line of road where stone, gravel, and other materials that are wanted, are to be most conveniently had; as by that means he will evade the slow and expensive mode of common cartage.

The immense sums that have been invested in the hands of certain companies, for the purpose of establishing general lines of rail-road throughout the country, have excited much interest and elicited many able papers from practical men, in several of the publications of the day. Amongst these, perhaps those inserted in the Scotsman, an Edinburgh newspaper, and in the Manchester Guardian, are the most deserving of our notice.

The Scotsman first commences with some theoretical statements, and then continues:

Having developed the theory of the motion of carriages on horizontal railways, we shall have little more to do with mathematical discussions, and shall now turn our attention to points of a practical nature, better adapted to the taste of ordinary readers. But first, we shall bring under the eye again, the effect of a given quantity of power on a railway, and on a canal, in a calm atmosphere—for it is only in a calm atmosphere that the results can be properly compared.

We have found that a *boat* weighing with its load 15 *tons, and a wagon of the same weight*, the one on a canal, and the other on a railway, would be impelled at the following rates, by the following quantities of power—which we have stated both in pounds and in horse power—reckoning one horse power equal to 180 pounds.

	Boat on a Canal.		Wagon on a Railway.	
Miles per hour.	power in pounds.	Horse power.	power in pounds.	Horse. power.
2 - -	33	1-5th. - -	100	½
4 - -	133	2-3ds. - -	102	½
6 - -	300	1¾ - -	105	½
8 - -	533	3 - -	109	½
12 - -	1200	7 - -	120	2-3ds.
16 - -	2133	12 - -	137	¾
20 - -	3325	18 - -	158	1

We have not taken into account the time lost in overcoming the *inertia* of the wagon where a small power is applied, because, in point of fact, the casual resistance of the wind would render it necessary to provide double or triple the power above stated. But if necessary, the time lost by the slow motion at first might be saved. Suppose there are a certain number of places where the steam-coach or wagon was to stop, to take in or put out passengers or goods; and farther, that the wagon, by travelling a few miles, has acquired an uniform velocity of 20 miles an hour. Then, if it is made to ascend an inclined plane of 10 feet perpendicular height, this velocity will be extinguished, and the vehicle will stop at the head of the plane. When it is to proceed again on its journey, its descent along an inclined plane of the same height on the other side, will enable it to recommence its career in a few seconds with the full velocity of 20 miles an hour. By raised platforms of this kind, at the two extremities of the journey, and at the intermediate stages, the velocity thus generated might be treasured up for permanent use. The platforms should be of different heights, corresponding to the various velocities of the vehicles plying on the railway. But in point of fact, the terminal velocity is attained so soon from a state of rest, that this contrivance would pobably be found unnecessary.

Where locks or *lifts* occur, the stationary steam-engine should drag up the vehicle, (supposing it to be along an inclined plane,) not simply from the one level to the other, but to a platform some feet above the higher level, that the vehicle by its descent might recover the lost velocity. It is plain, however, that when the difference of level did not exceed eight or ten feet, the momentum of the vehicle would carry it up without any assistance from a stationary engine, and with merely a small temporary loss of velocity.

Some persons imagine erroneously that teethed wheels and rackwork would be necessary where the railway was not perfectly level. But the friction of iron on iron being 25 per cent. of the weight, if the whole load was upon the wheels to which the moving power was applied, and if the quantity of power was sufficient, the wagon would ascend without slipping, though the plane rose one foot in four—while even cart roads scarcely ever rise more than one foot in 18 or 20. If four-fifths of the load, however, were placed on separate cars, and only one-tenth of the whole pressure, for instance, was upon the axle to which the moving force

was applied, the power of ascent by friction would only be one-tenth of one foot in four, or one foot in forty.

The steam-engine, as we commonly see it, is so bulky, and with the addition of its fuel and supply of water, so ponderous, as to create an impression on a first view, that its whole power would scarcely, under the most favourable circumstances, transport its own weight. The steam-boat, however, which cuts its way through the ocean in defiance of tide and tempest, shows that this is a mistake. For all velocities above four miles an hour, the locomotive engine will be found superior to the steam-boat; that is to say, it will afford a greater amount of *free* power, above what is required to move its own weight.

We have seen various statements respecting the locomotive engine, few of them so detailed as could be desired—from which we subjoin the following particulars:

Trevithick and Vivian's high-pressure locomotive engine, with a cylinder of eight inches diameter, and a pressure of 65 pounds per square inch, (apparently about eight-horse power,) drew carriages containing ten and a half tons of iron, at five and a half miles per hour, for a distance of nine miles. (Stuart's History of Steam-Engine, p. 164.) Whether on a road or railway is not mentioned.

We find it stated in a Liverpool paper, as the result of inquiries made respecting the locomotive engines, that one of these, of ten-horse power, conveys fifty tons of goods at the rate of six miles an hour on a level railway. But was the road an edge or tram-road?

Mr Blenkinsop states, in replies to queries put by Sir John Sinclair, that his patent locomotive engine, with two eight-inch cylinders, weighs five tons, consumes 2-3d cwt. of coal, and fifty gallons of water per hour, draws 27 wagons weighing 94 tons on a dead level, at three and a half miles per hour, or 15 tons up an ascent of two inches in the yard; when 'lightly loaded' travels 10 miles an hour, does the work of 16 horses in 12 hours, and costs 400*l*. Another person says, that the weight of this engine with its water and coals is six tons, and that it draws 40 or 50 tons, (wagons included,) at four miles an hour on a level railway. (Repertory of Arts, 1818, p. 19-21.) This seems to have been a high-pressure engine of about eight or ten-horse power. But we are not informed what sort of railway it worked on, how long its journies were, or what is meant by 'lightly loaded.'

We shall take for granted then that an eight-horse

power high-pressure engine, with its charge of water and coal, and with the car which bears it, weighs six tons, and that it requires an additional supply of 100 weight of coal and 400 weight of water for each hour it works. This is very consistent with other ascertained facts. We find, for instance, in the parliamentary report on steam navigation, that the low-pressure engines used in vessels, which are made twice as strong as stationary engines, weigh about one ton and one-fifth for each horse power, including their charge of water and coal. Now the high-pressure engines want the condensing apparatus, which must diminish the weight probably by one-fourth part. The estimate for coal we have increased one-half, because we think it rather below the truth. It is only about nine pounds per hour for each horse power, while Mr Watt allows twelve pounds for his low-pressure engines.

It follows, therefore, that an eight-horse power locomotive engine with coal and water for eight hours, would weigh eight tons. Hence, bulky and ponderous as the steam-engine appears, we find that a locomotive engine, weighing eight tons, moves 50 tons besides itself, (taking the more moderate estimate,) that is, it consumes only one-seventh part of the power it creates, when travelling at four miles an hour; or *the free power applicable to other purposes, is seven-eighths of the whole.* This is the result of an early experiment, made probably upon a rail-road not of the kest kind, and with vehicles much less perfect than they may yet be rendered. Though it falls much under the effect calculated theoretically, it does not strike us as being inconsistent with the truth of the principles on which the calculation was founded.

The high-pressure engine, on account of its smaller weight and bulk, is evidently best adapted for railways; and it can be used with perfect safety, because it may be easily placed in a car by itself, a few feet before the vehicle in which the passengers are. The vehicle itself, by its regular and steady motion on the railway, would answer the purpose of a *fly-wheel* in the most perfect manner. The engine might run upon six wheels, which should be locked together by teeth pinions, that the tendency to slip might be resisted by the friction of the whole mass of eight tons.

The best form of a steam-coach for the conveyance of passengers would probably be the following:—A gallery seven feet high, eight wide, and 100 feet in length, formed into 10 separate galleries 10 feet long each, connected with

each other by joints working horizontally, to allow the train to bend where the road turned. A narrow covered footway, suspended on the outside over the wheels on one side, would serve as a common means of communication for the whole. On the other side might be outside seats, to be used in fine weather. The top, surrounded with a rail, might also be a sitting place of promenade, like the deck of a track boat. Two of the 10 rooms might be set apart for cooking, stores, and various accommodations; the other eight would lodge 100 passengers, whose weight, with that of their luggage, might be 12 tons. The coach itself might be 12 tons more; and that of the locomotive machine, eight tons, added to these, would make the whole 32 tons. Each of the short galleries might have four wheels; but to lessen the friction, the two first wheels only should be grooved, the two last cylindrical, and three or four times as broad as the thickness of the rail. The conveyance of goods would be effected by a train of small wagons loosely attached to each other.

It will be observed from the table we have given above, that it would require seven-horse power to impel a steamboat weighing 15 tons at 12 miles an hour. This gives a load of two tons so moved; however, the engine, if a low-pressure one, with water and eight hours' coals, would weigh nearly ten tons, and the vessel would weigh at least five; so that the whole power of the engine would be expended in impelling itself and the ship containing it, at the supposed rate, and no *free* power would remain for freight. Facts show that the resistance is actually rather greater in water than theory in this case represents it. We have calculated from data furnished by the Parliamentary Report on steam navigation, that the entire burden on the engine in vessels going only eight or nine miles an hour in calm weather, rarely exceeds three tons for each horse power, while, according to the table, it should be five tons. Indeed, in our common steam-vessels for passengers, going eight or nine miles an hour, the ship and engine may be considered as constituting the whole burden. For 50 passengers, weighing perhaps with their luggage six or eight tons, placed on board a ship weighing, with her engine of 60 or 70 horse power, a hundred and fifty or hundred and eighty tons, form but an addition of one-twentieth or one-thirtieth to the mass—a quantity of no importance in a practical point of view. If we convert the steam-engine power into real horse power, and figure to ourselves 100 horses employed to

draw 50 persons, we see what an enormous waste of power there is in the mode of conveyance. We may remark further, that the tenor of the evidence given before the Parliamentary Committee, renders it extremely doubtful, whether any vessel could be constructed, that would bear an engine capable of impelling her at the rate of two miles an hour, without the help of wind or tide.

When the steam-coach is brought fully into use, practice will teach us many things respecting it, of which theory leaves us ignorant. With the facilities of rapid motion which it will afford, however, we think we are not too sanguine in expecting to see the present extreme rate of travelling doubled.

This practicability of conveying individuals or merchandize at the speed required in the present improved state of our internal intercourse with the different parts of the kingdom, has created much doubt and discussion with many able and practical mechanics. The question seems to resolve itself thus, Do the friction incurred by any moving body, laying aside the resistance of the atmosphere, increase in proportion to its velocity?

Without going into any diffuse or theoretical argument on this point, we shall merely cite that by the results of actual experiments instituted by Vince and Coulomb, it appears *that friction does not increase in proportion to the velocity.*

By experiments made also by Stephenson and Wood, it appears that the force required to keep a given weight in motion does not vary with the velocity: thus, a force of 14 lbs. was found to overcome friction, and keep in motion an empty coal wagon, weighing 23.25 cwt. on a rail-road; and that on doubling the velocity, no more force was required. Further also it appears, that on increasing the weight, or load, the power required to overcome the friction, and keep the wagon in motion, did not increase in similar proportion, but up to 76.25 cwt. was about one-fourteenth less.

Notwithstanding the simple and satisfactory manner by which the experiments that led to these results were conducted, the fact has been still much doubted. We cannot therefore do better than to extract from the Manchester Guardian the following article, which contains an account of experiments, with most conclusive results, made by that able mechanic, Mr Roberts of Manchester:

"The object of the papers on rail-roads which appeared in the Scotsman, was, in a great measure, to show the prac-

ticability of transporting commodities upon rail-roads, at a very considerable speed; and, (with some fallacies, which we shall endeavour to point out,) they contain a great deal of valuable information, on the relative merits of highways, canals, and rail-roads. The principal point, however, and the one to which we shall confine our observations, is an ennunciation of the laws which regulate the friction of rolling and sliding bodies, as deduced from the experiments of Vince and Coulomb. With a view to the illustration of this part of the subject, some very important and conclusive experiments have recently been made in this town, to which we shall by and by have occasion to refer at some length; but before doing so, we must make a few observations on the rule laid down by the Scotsman, and the misconceptions which appear to have prevailed respecting it, both in that journal and in other quarters.

After comparing the resistance experienced by a boat moving through the water, with the friction which retards the progress of a wagon on a rail-road, and stating that they are governed by different laws, the Scotsman notices the conclusions established by the experiments of Vince and Coulomb; the most important of which is, that the *friction of rolling and sliding bodies is the same for all velocities*. The writer then observes:

'It is with this last law only that we have to do at present; and it is remarkable that the extraordinary results to which it leads, have been, as far as we know, entirely overlooked by writers on roads and railways. These results, indeed, have an appearance so paradoxical, that they will shock the faith of practical men, though the principle from which they flow is admitted without question by all scientific mechanicians.

'First. It flows from this law, that, (abstracting the resistance of the air,) if a car were set in motion on a level railway, with a constant force greater in any degree than is required to overcome its friction, the car would proceed with a motion continually accelerated, like a falling body acted upon by the force of gravitation; and however small the original velocity might be, it would in time increase beyond any assignable limit. It is only the resistance of the air, (increasing as the space of the velocity,) that prevents this indefinite acceleration, and ultimately renders the motion uniform.

'Secondly. Setting aside again the resistance of the air, (the effects of which we shall estimate by and by,) the very

same amount of constant force which impels a car on a railway at two miles an hour, would impel it at ten or twenty miles an hour, if an extra force were employed at first to overcome the *inertia* of the car, and generate the required velocity. Startling as this proposition may appear, it is an indisputable and necessary consequence of the laws of friction.

'Now it would at all times be easy, as we shall afterwards show, to convert this accelerated motion into a uniform of any determinate velocity; and from the nature of the resistance, a high velocity would cost almost as little, and be as readily obtained as a low one. For all velocities, therefore, above four or five miles an hour, railways will afford facilities for communication prodigiously superior to canals, or arms of the sea.'

Now we are perfectly satisfied, both by the experiments of Vince and Coulomb, and those more recent and conclusive experiments, to which we have already alluded, that the rule laid down here is correct; but the writer ought to have guarded against the misconception to which his last paragraph is liable. When he says that a high velocity would cost almost as little as a low one, he should have said that it would cost as little per mile, or as little over any given space: for it cannot be his meaning, that a carriage can be kept moving for an hour, or for any given time, at a high velocity, with as little expenditure of power, as at a low velocity. Yet this he has been generally understood to mean, and a great deal has been written and said with a view to prove that he was mistaken, when in fact he was only misunderstood. In a subsequent article, however, the author appears, in some degree, to have fallen into the same error into which he has led other persons. He says:

'Every body knows that the rate of stage-coach travelling in this country has increased within the last twenty-five years, from six or seven miles an hour to eight or nine, and this, too, before roads were McAdamized, and with much less injury to the horses than was anticipated. Supposing that a coach-horse could run fourteen miles unloaded, with the same muscular exertion which carries forward the stage-coach at eight or nine miles, then professor Leslie's formula becomes 3-4ths $(14\ v)\ 2$. Each horse would, of course, draw with a force of 48 lbs. at six miles, and of 27 lbs. at eight miles an hour. But if the friction increased in the ratio of the velocity, the load upon each horse would increase from

48 lbs. to 60 lbs., when the speed increased from six to eight miles an hour: and as the horse exerting the same strength would only pull with a force of 27 lbs., he would thus have more than double work to do, which is plainly impossible. But admit that the friction is equal in equal times; then, since the time is diminished 1-4th by increasing the speed from six to eight miles an hour, the horses have actually 4-5ths less to do; the load upon each is reduced from 48 lbs. to 36, and the horse would have to increase its exertion only 1-3rd, that is, from 27 lbs. to 36. The facts, we believe, will be found strictly consistent with this hypothesis, and decidedly at variance with the other. However strange it may sound, then, to common observers, it is practically true, that a smaller absolute amount of force will drag a coach over the same space in three hours than in four, and in one than in two.'

This paragraph seems to us to contain a very obvious fallacy. If the speed be increased from six miles an hour to eight, the horses have by no means 1-4th less work to do, supposing the friction a constant quantity, and the traction consequently the same. It is true that they exert this power for a shorter time, but it is over the same distance. Supposing the power of traction necessary to overcome the friction is 1000 lbs., then that power must be extended over every yard of the distance, whether the carriage moves at six or eight miles an hour: and it is by the distance, not the time, that the power must be measured. That this must be the case, will be obvious if the experiment be put in another shape. Suppose a perfectly horizontal railway, a mile long, with a perpendicular descent of a mile at one end of it, as represented in fig. 652.

Suppose a wagon placed on this railway at A, attached to a rope passing over a pulley at B, and loaded at that point with a weight exactly sufficient to overcome the friction, then, if the resistance of the air is nothing, and the rope be without weight, it follows, from the rule laid down, that if the wagon is set in motion at any given speed, it will continue to move at that rate, until it reaches the point B and the weight falls to C. But whether the wagon passes over the railway in an hour or in three minutes, it is obvious that the same weight will descend through the same space, and that consequently, the same amount of power will be expended. It is, perhaps, necessary to observe here, that if the weight is only just sufficient to overcome the friction, there will, (as is proved by

the experiments of Mr Vince,) be no acceleration of motion on the principle of falling bodies.

However, though a carriage cannot, as we think we have shown, be moved ten miles in one hour, with a similar expenditure of power as in two, it is very interesting to know that it can be moved with the same expenditure, (excepting the resistance of the air.) In many cases despatch is of so much consequence, that the elucidation and application of this rule will probably lead to very important results. Many persons, however, are very sceptical on this subject, and contend that the experiments of Vince and Coulomb do not authorize any such conclusions as have been drawn from them. It has been asked, if the same constant force will move a carriage as well at a high as at a low velocity, why we do not see something like this in practice; why a carriage moved by a steam-engine instead of acquiring, as it proceeds, a high degree of velocity, moves on at one uniform rate after it has overcome the *vis inertiæ* at the commencement of its journey? We think the reason is very obvious. A locomotive steam-engine does not exert the same constant force on the peripheries of the wheels of the carriage, when it moves at different velocities. For instance, suppose the piston of an engine to move 220 feet in a minute, and to impel the peripheries of the travelling wheels at a velocity of two miles, and with a force just sufficient to overcome the friction, how can the speed be augmented without increasing the power of the engine? If the diameter of the wheels be increased with the view of increasing the speed, the force with which they are impelled will be diminished in the same proportion; and the engine will stop, unless the pressure is increased. To increase that, of course, will be to augment the power. As it is obvious, therefore, that a steam-engine cannot exert the same force at different velocities, some other means must be devised for putting to the test of experiment the rule laid down in the *Scotsman*.

We now come to the most important and interesting part of this article. As none of the experiments of Vince or Coulomb, (so far as we have seen or heard them detailed,) were made with bodies resembling railway wagons, either in form, or in the nature of their motion, the correctness of the conclusions deducted from them with respect to such carriages, was doubted by many persons of considerable scientific attainments. It became desirable, therefore, that other

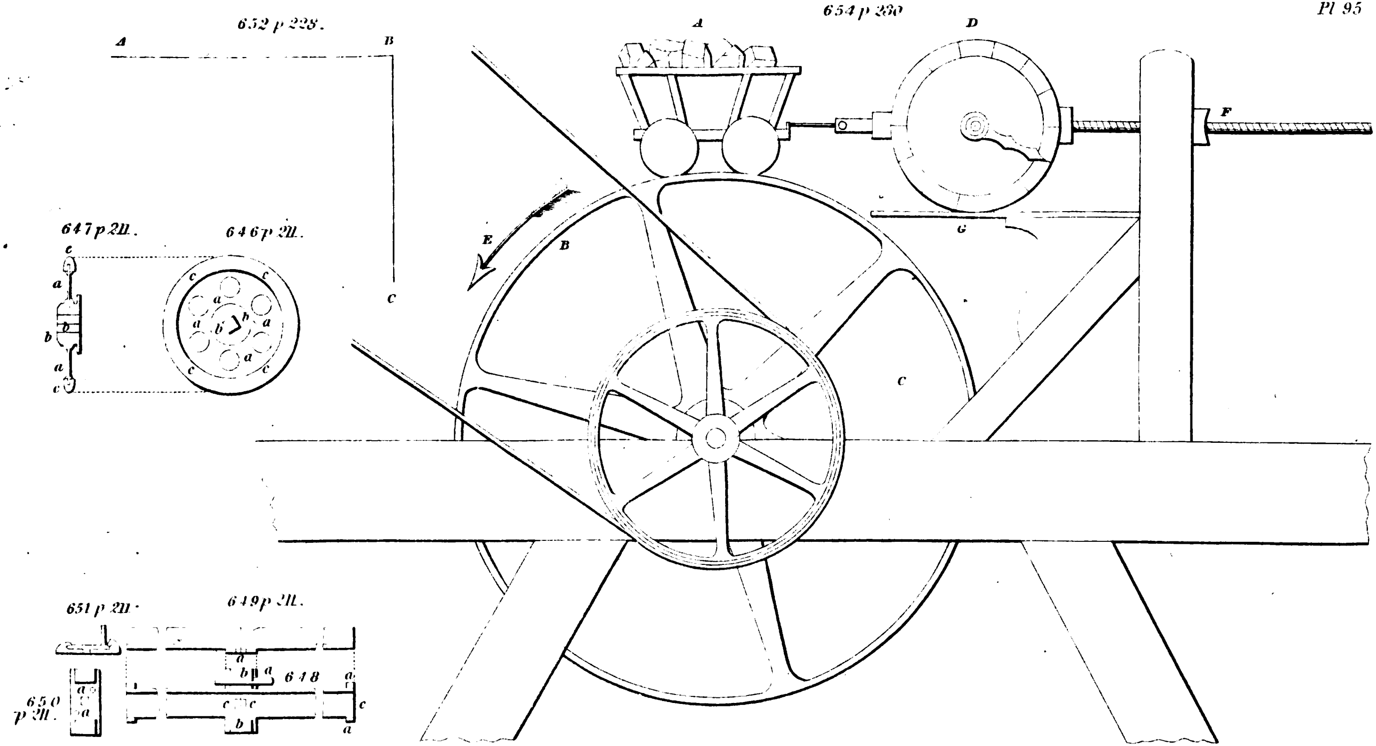
experiments should be tried, with carriages upon railways, which, of course, would be much more satisfactory. This, however, it did not at first sight appear very easy to accomplish in a satisfactory manner: but Mr Roberts, of this town, recently devised a mode of determining the point, which appears to us wholly unobjectionable, and which exhibits, in a high degree, the simplicity and facility of execution, by which that gentleman's inventions are so eminently distinguished. It was very difficult to devise means for measuring accurately the friction of a carriage moving over a railway; but it occurred to Mr Roberts, that the difficulty would be obviated if the railway were made to move under the carriage. When this idea once presented itself, it was easy to reduce it to practice. Mr Roberts therefore constructed an apparatus, of which fig. 654 will give a pretty correct notion.

A is a small wagon with four cast-iron wheels, placed on the periphery of a cast-iron drum B, three feet in diameter, and six inches broad, (which acts as the rail-road.) This drum is fastened on the same shaft as the pulley C, which is driven at different speeds by a strap from another pulley. The wagon is attached by a wire to one of Marriot's patent weighing machines D, for the purpose of measuring the friction, and the board G prevents the current of air, occasioned by the motion of the drum, from acting upon the carriage. Now if the drum be driven with any given velocity, say four miles an hour, in the direction indicated by the mark E, and the wagon held in its place by the wire which attaches it to the index, it is perfectly obvious that the wheels will revolve on the drum in precisely the same manner as if the wagon moved forward on a horizontal road; and the friction will also be the same, except, perhaps, a small addition occasioned by the curvature of the drum, but which will not affect the *relative* frictions of different speeds. As the wagon is stationary, the resistance of the air will be entirely got rid of; and the index of the machine will indicate the precise amount of traction necessary to overcome the friction. Of course, in making the experiment, it will be necessary to keep the centre of the wagon *exactly over the axis of the drum;* for if it were permitted to go beyond the centre, a part of the weight would be added to the friction; if, on the contrary, it was brought nearer the index, a part of the weight would act against the friction, and diminish the apparent quantity. The tempering screw, F, is therefore added to keep the wagon in its proper situation, in whatever way the spring of the weighing machine may be acted upon by the friction.

This simple apparatus having been constructed, a number of experiments were made, chiefly with a view to determine whether the friction is the same at different velocities. The wagon was loaded with fifty pounds, (including its own weight,) and the drum was driven at different velocities, varying from two to twenty-four miles an hour on the periphery: but in every case, the friction, as indicated by the weighing machine, was precisely the same. No increase of speed affected the index at all, but on increasing the weight, it immediately showed a corresponding increase of friction.

We consider these experiments as perfectly conclusive

From 646 to 652



LOCOMOTIVE ENGINE.

of the fact, that the friction on a railway is the same for all velocities; and that a carriage may be propelled twenty miles in one hour, with the same amount of force which would be necessary to drive it twenty miles in ten hours, provided the resistance of the atmosphere was out of the question; and if the carriage was properly constructed, that would not amount to much. In other words, goods may be conveyed from Manchester to Liverpool, on a rail-road, with very nearly the same expenditure of steam, whether they are carried two miles, or four miles, or twenty miles an hour. A steam-engine, which will propel twenty tons at four miles an hour, will, with the same expense of coals, propel ten tons at eight miles an hour; so that, with the smaller load, it might make a journey to Liverpool and back in the same time which would be occupied in going thither with the larger load. Or, to put the matter in another shape: suppose a four-horse engine will convey forty tons to Liverpool in eight hours, an eight-horse engine will convey the same weight thither in four hours. There will be the same expenditure of steam in both cases, but, in the latter, a saving of half the time; a saving which, we need not add, will frequently be of immense importance."

These practical results are very satisfactory, as the hope of propelling carriages at a suitable speed, for the more rapid dispatch of business, and conveyance of passengers, is thereby placed almost beyond a doubt.

We ought to notice here the striking difference in the force requisite to give rapid motion on a rail-road to that on a canal or navigable river. These latter are governed by a totally different law, as the resistance, or head of water on the bows of the boat, increase as the squares of its velocity; consequently it will require four times the power to double the speed. But, on the other hand, it must be admitted, that in all speeds under three miles per hour, the canal has a decided advantage, as the force increases as the speed diminishes.

With respect to the horse, it is well known that his power decreases as his speed increases; and that when he is travelling at his greatest speed, which, with a weight, seldom exceeds 13 miles per hour, he is able to exert little or no strength. We, therefore, take it for granted, that in the present improved state of our manufactures, artificial power of some description must be resorted to, and whatever experience may prove to be the most economical, the application of that power is the most important part of the subject now

under consideration. On this point, the data with which we are furnished is so very limited, as scarcely to render it possible to form any decisive opinion.

The engines which have been some time at work at Mr Brandley's collieries, near Leeds, have a cogged wheel, playing in a rack, which is laid as one of the rails of the road; and those at Hetton colliery are much on the same principle. This plan is objectionable, because the whole weight of the engine, which on the most improved construction, is not less than eight tons, is on the wheel, so that any obstacle on the rail must of necessity shake the whole machinery. To obviate this, Mr Gordon has contrived, and taken out a patent for a locomotive carriage with the engine on springs, which imparts the motion without any connexion with the wheels or axle-tree, and there are various other plans in progress for the same object. But let this be effected as it may, the great weight of the engine, which is by far the greatest objection, is not obviated. And, indeed, this appears to us only possible to be accomplished, by either diminishing the weight of the engine, as proposed by the application of Mr Brown's pueumatic, or vacuum engine, or taking the engine entirely from the carriage, and employing stationary engines, at suitable distances, to tow or draw the carriages in regular succession. This last mode has been applied to practice in the vicinity of Newcastle, by Mr Thompson; and the results may be seen in some very able observations annexed to the specification of his patent, and inserted in the Repertory of Arts for March 1822.

His method consists in dividing the line of rail-road into any number of stages, at suitable distances apart. At the end of each stage an engine is erected for the purpose of drawing the carriages from the next stage, or engine, on either side, towards itself. This is effected by means of ropes, which, previously to commencing operation, are taken from each respective engine to the engine immediately before it by horses; but after the work has commenced, by being hooked at the end of the advancing or returning carriages.

In forming lines of rail-road upon this system, that is, where stationary engines are to be employed, it is not necessary that they incline in the direction of the loads, or be made perfectly level. For in engines of this description there is no occasion to pay that particular attention to the weight of the boiler and appurtenances, as is the case in engines

which have a locomotive principle. Indeed trifling inequalities of surface, which would be a material objection in the application of locomotive carriages, are, in the lines of road where stationary engines are employed, quite unheeded.

As many roads are traversed by night as well as by day, it becomes necessary that a signal should be given from one engine to the other as soon as the carriages have arrived and are hooked to its respective ropes, that the engine tender may not be at a loss when to throw his machinery into geer. For this purpose, Mr. Thompson recommends that the door of the fire-place of the boiler, or other strong light, be placed towards the engines on each side, so that, by opening it on that side which faces the engine, to whose ropes the carriages just arrived have been attached, the engineer may adopt such measures as will effect the desired purpose.

It is true, locomotive engines were not at that period so well understood as at present; but it appears to us that this point still remains in a very undecided state, and that from the even now limited experience in propelling carriages on railways, at a speed any thing like that of common carriages, it is very difficult to hazard an opinion. From the data, however, that can be collected, we certainly incline to stationary engines, as the most mechanical and economical application of the requisite power.

As to the degree of danger which travellers may be exposed to by locomotive engines, it cannot, under a proper management, exceed that of a steam-boat, or a factory where power is operating. It is true, that as the weight of the engine is of great consideration, condensing engines, (if steam be the force employed,) are quite inapplicable, and what are generally called high-pressures must be introduced. But though all engines which do not condense their steam, and act only by the pressure, or elastic force, are called high-pressure engines, there is no necessity whatever to go to dangerous heats, and with either wrought iron or copper boilers and valves, placed out of the reach of the operative engineer, or engine tender, may certainly be worked at 45 or 53 lbs. pressure with as much safety as at 20 lbs. in condensing engines. Indeed, on investigating the cause of steam explosions, they will be found to have rarely occurred but from the grossest ignorance and neglect.

Such of our readers who are desirous to have farther information on this interesting subject, we must refer to a very

able report on rail-roads, by Mr Charles Sylvester, to the paper alluded to by Mr Thompson, in the Repertory of Arts, for March, 1822, to a work which has lately issued from the Press, by Mr N. Wood of the Killingworth Colliery, of whose experiments, in conjunction with Mr Sylvester, we have already had occasion to speak, and to Observations on a General Iron Railway, by Mr Gray.

[Description of a *Merchant Flour-Mill* driving four pair five feet mill-stones, arranged by *Cadwallader & Oliver Evans, Engineers, Philadelphia.*

1. A hollow cast-iron shaft, circular, 15 inches in diameter, except at those points where the water and main bevel-wheels are hung, where it is increased to 19 inches in diameter. The water-wheel is secured on this shaft by three sockets represented and described, Plate 96, Fig. 3, and makes 10 revolutions per minute.

2. The main driving bevel-wheel on the water-wheel shaft, 8 feet in diameter to the pitch-line, 100 cogs, 3 inch pitch, and 8 inches on the face, revolving ten times per minute, and driving

3. A bevel-wheel on the upright, 4 feet in diameter to pitch-line, 50 cogs, same pitch and face of cogs as above, revolving 20 times per minute.

4. The large pit spur-wheel, making 20 revolutions per minute, 9 feet 1.5 inch diameter to pitch-line, 114 cogs, 3 inch pitch, face 10 inches. This wheel gives motion to

5, 5, 5, 5. Four pinions on the spindles of the mill-stones, 18.1 inches in diameter to pitch-line, 19 cogs, same face and pitch.

6, 6, 6, 6. Iron upright shafts, extending the height of the building, and coupled at each story.

7, 7, 7, 7. Are 4 pair five feet mill-stones, making 120 revolutions per minute, two of them shown in the elevation, and the position of the four shown in Plate 97, as represented by the dotted lines, Fig. 1.

8. A pulley on the upright shaft, which by a band gives motion to the fan for cleaning grain, revolving 140 times per minute, wings 3 feet long, 20 inches in width.

9. A bevel-wheel 2 feet diameter, cogs 2 inch pitch, face 2.5 inches on the upright shaft, gearing into a bevel-wheel; the face, of which is shown, drives the bolting-screen 18 revolutions per miuute.

10. A bevel-wheel on upright shaft, 56 cogs, 2 inch pitch, 2.5 inches, face gearing into

10. A bevel-wheel on the shaf of the bolting-reels, 31 cogs, same pitch and face.

10, 10. Are two of four bolting-reels shown, 18 feet long, 30 inches diameter, revolving 36 times per minute.

11. A large pulley on the upright shaft, which by a band gives motion to the rubbing-stones 11.

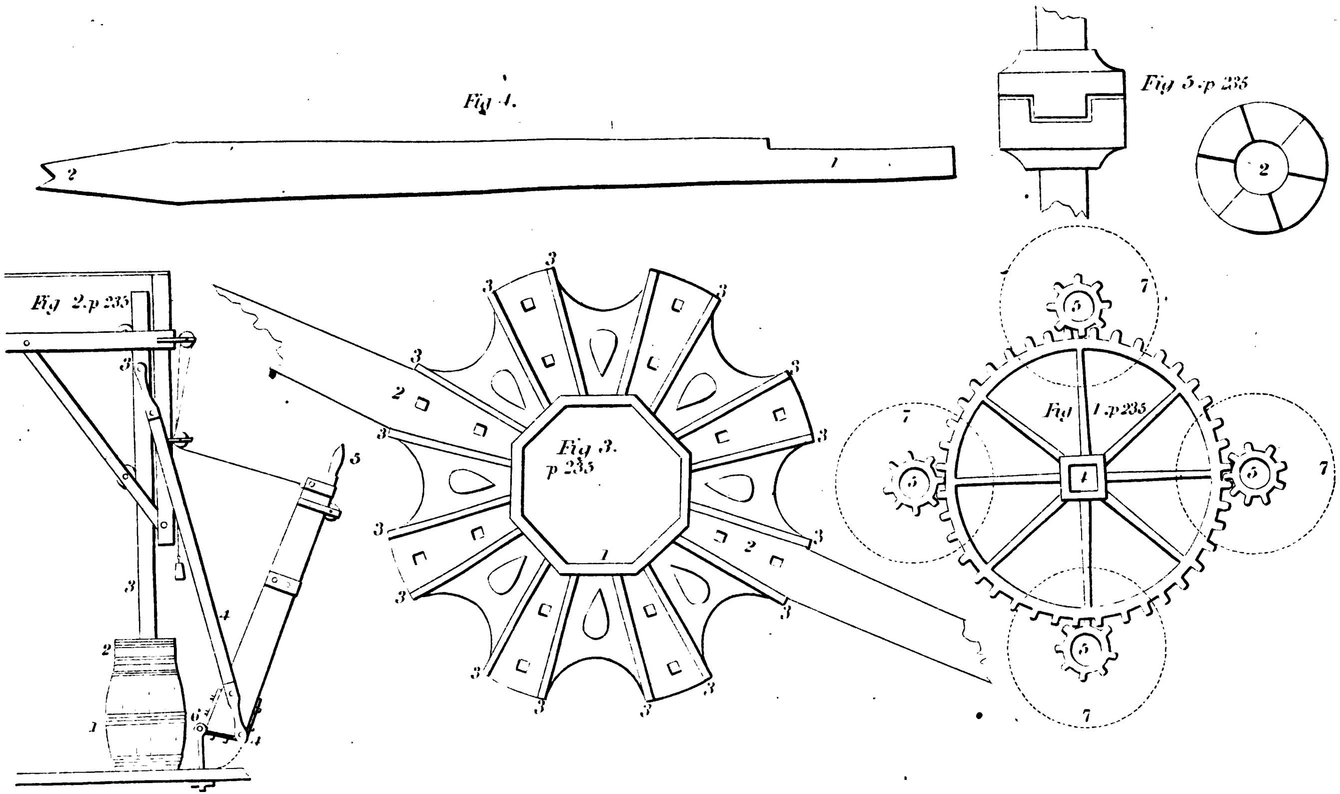
12. A bevel-wheel on the top of the upright shaft, gearing into

12. A bevel-wheel on the horizontal shaft, at one end of which is

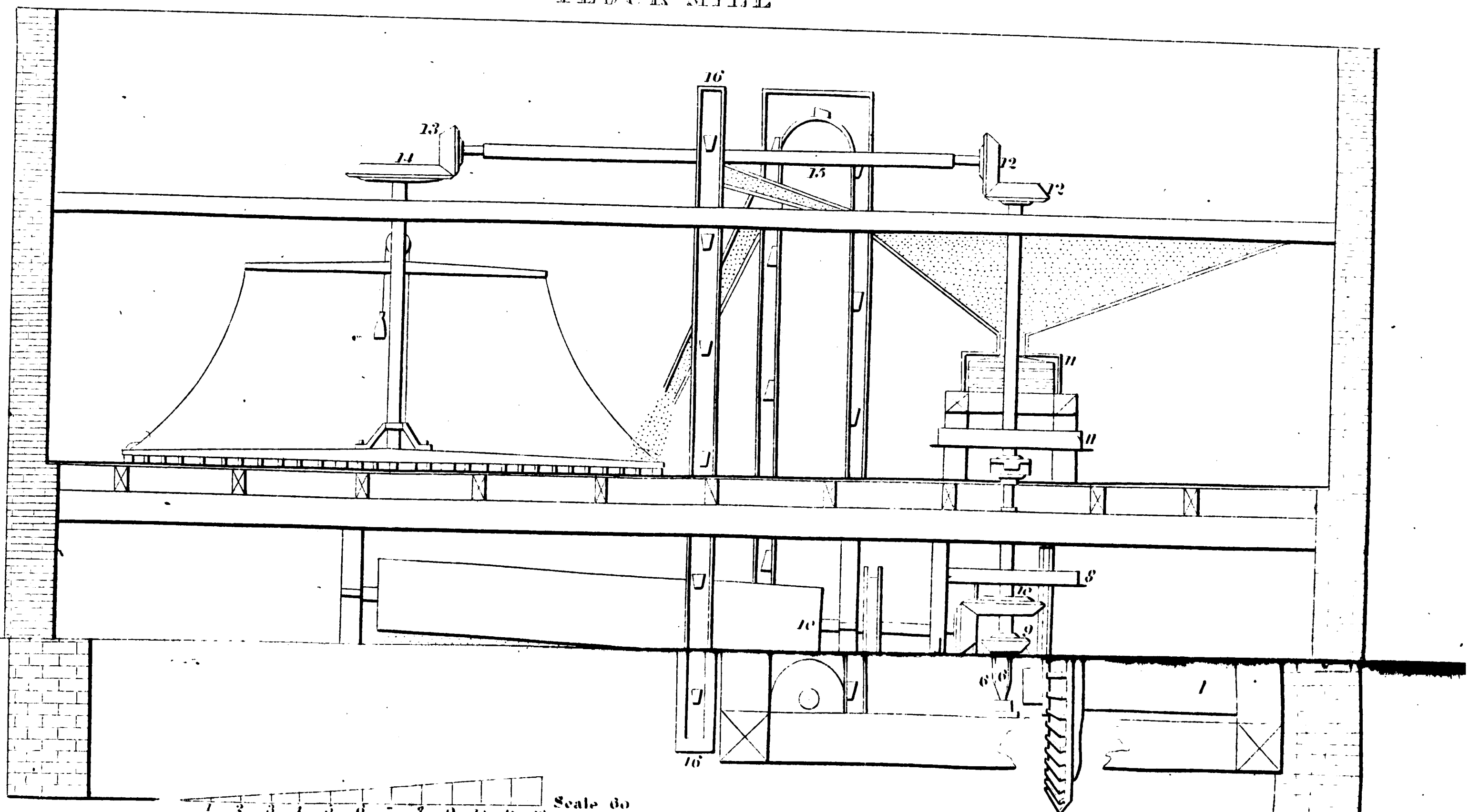
13. A bevel-wheel, one foot diameter, gearing into a bevel-wheel

14. Of 5 feet diameter, which reduces the motion of the hopperboy down to four revolutions per minute, which sweeps a circle of 20 feet.

FLOUR MILL.



FLOUR MILL



15. Meal-elevator, attending 4 pair stones.
16. Crain-elevator.
17. Packing-room and press.

Plate 97, Fig. 1. A bird eye view of the mode of giving motion to 4 pair mill-stones.

4. The large pit spur-wheel, driving at equal distances on its periphery the pinions

5, 5, 5, 5. Attached to the spindles of the mill-stones.

7, 7, 7, 7. Mill-stones 5 feet diameter, represented by dotted circles.

Fig. 5. An enlarged view of the couplings for the upright shaft. They are of cast-iron, with their holes truly reamed to receive the ends of the iron upright shafts. 2. The face of a coupling, divided into six equal parts radiating from the centre, three of the parts project and three are depressed, so that when two of them are coupled, the projection of one will fill the depressions in other, as 1, the coupling, connected.

Fig. 3. A cast-iron socket for the water-wheel; it is a plate $\frac{3}{4}$ inch thick; the eye for the shaft to pass through $1\frac{1}{4}$ inch thick and 12 inches deep; the sockets for receiving the arms are 14 inches long, and have projections 5 inches deep, 333, &c. the projections, the intermediate space between the sockets are cut out to lessen the weight of metal, but must be in such a manner as to preserve the strength. It requires three of these sockets for a large water-wheel; the arms for receiving the buckets are dressed to fit tightly in the sockets, and secured firmly by bolts as 2.2.

Fig. 4. An arm for the water-wheel as dressed; 1, the end to be bolted in the socket; 2, the end for screwing on the bucket.

The advantages of this mode of constructing water-wheels are, the shaft is not weakened by having mortises cut in it to receive the arms, that it is not so liable to decay, and if an arm or bucket is destroyed by accident, they can be dressed out, and the mill stopped only while you unscrew the broken part and replace it by a new one.

Fig. 2. An elevation of the flour-press; 1, the barrel of flour; 2, the funnel; 3, 3, the driver; 4, 5, the lever; 4, 3, the connecting bars fastened by a strong pin to each side of the lever at 4, and to the driver at 3; 6, a strong bolt passing through the floor and keyed below the joist; there is a hole in the upper part of the bolt to receive a pin which the lever works on, and when brought down by the hand, moves the pin 4 in the dotted circle, the connecting bars drawing down the driver 3, 3, forcing the flour into the barrel; and as it becomes harder packed the power of the machine increases; as the pin 4 approaches the bolt 6, the under sliding part of the lever is drawn out to increase its length, and is assisted in rising by a weight fastened to a line passing over pullies.

When the pin 4 is brought down within half an inch of the centre of the bolt 6, or plumb-line, the power increases from 1 to 288; and with the aid of a simple wheel and axis, is as 1 to 15; from 288 to 8640; that is to say, one man will press as hard with this machine as 8640 men could do with their natural strength. It is extremely well calculated for cotton, tobacco, cyder, or, in short, any thing that requires a powerful press.

Operation of the Mill. The grain, after having been weighed, by drawing a slide, is let into the grain-elevator 16, there hoisted to the top of the building, and by a spout moving on a circle, can be deposited into spouts leading to any part of the mill; when wanted for use, by drawing sliders on other spouts conveying the grain-elevator 16, can be re-elevated, and thrown into the hopper of the rubbing-stones 11, after passing through which, it descends into the bolting-screen 9, and when screened, falls in the fan 8, is there cleaned, and from that descends into a very large hopper, over the centre of the four pair mill-stones, which are supplied regularly with grain. After being

ground, the meal descends into a chest, is taken by the elevator 15 to the top of the building, there deposited under the hopperboy, which spreads, cools, and collects it to the bolting-reels, where the several qualities are separated, and the flour descends into the packing-room 17, where it is packed in barrels.

By this arrangement, we dispense with all conveyers, and have only one grain and flour-elevator to attend to four pair stones, and dispense with one-half of the quantity of gearing usually put in mills, and do not occupy near the space, leaving the rest of the building for storing grain, &c.

All the wheels in this mill are of cast-iron, and the face of the cogs very deep, for experience justifies that depth of face in cog-wheels, when properly constructed, does not increase friction; that the wheels will last treble the time by a small increase of depth: we recommend the main driving-wheels to be 10 inches on the face. The journals of all shafts where great pressure is applied should be of double the length now generally used. Increase of length does not increase friction; say for water-wheels from 8 to 14 inches. Journal draughts of mills furnished by the subscribers, and the cast-iron work can be obtained at the Steam-Engine and Iron-Foundry of Messrs Rush and Muhlenburg, Bush-Hill, Philadelphia.

CADWALLADER EVANS.
OLIVER EVANS.

The following account of the *Philadelphia Water-works*, has been furnished for this work by *Frederick Graff*, *Esq.* under whose direction they were constructed.

Plan and section of a Water-wheel and pump for raising water 96 feet perpendicular height. Plate 98.

A, plan of the water-wheel.
B, crank wheel.
C, connecting rod from the wheel to the pump.
D, plan of the pump.
E, the forebay which supplies the wheel and pump with water.
F F, the gates to forebay and water-wheel.

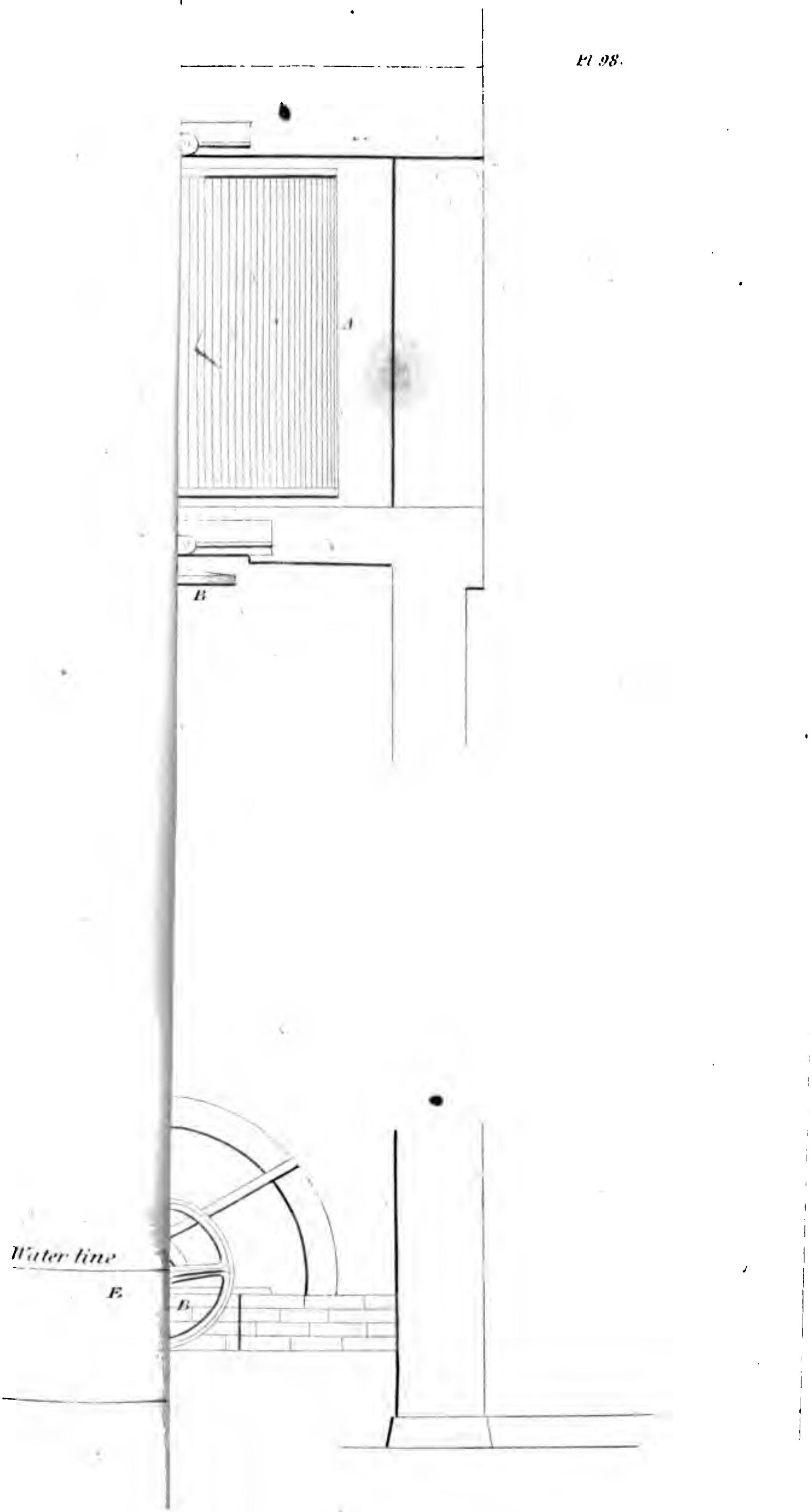
The water-wheel is 15 feet long and 16 feet diameter, and works under 1 foot head, and 7 feet 6 inches fall, and makes 13 revolutions per minute.

The pump is double, the working barrel of which is 16 inches clear in diameter, and the half stroke of the pump is 5 feet. The quantity of water raised is upwards of 1½ millions of gallons, ale measure in 24 hours.

Plan of the cast-iron pipes of conduit with double and half branches, circular-pipe, reducing-pipe, bevel-hub pipe, &c. as used at the Philadelphia Water-Works. Plate 99.

The laying of the pipes is very easy, care being taken to keep them firm in their bed—the hub, or large end of one, laps about four to six inches over the small end of the other, leaving a space of from one-fourth to one-half of an inch all round, which is first caulked in with a ring of plaited hemp, to prevent the lead running into the pipes; then a pair of nip-

Pl. 98.



pers, with a joint in the lower part to fit all round the pipes, and having an opening on the top for the lead, and another for the escape of the air, which will be shown in the annexed drawing, is affixed next to the opening on the outer part of the pipe, so as to prevent the lead coming out in front, which is further secured by a ring of clay, outside of the nippers, and formed into a cap at top, into which melted lead is poured, forming a ring of lead three or four inches in depth. When the lead is cold, the clay and nippers are removed, and it is then upset with a hammer and chisel, which completes the joint.

The following is a list of the average weight of pipes of different diameters in the clear, with the thickness required to bear a pressure of 300 *feet head of water, and the present prices.*

Diameter.	Thickness of the pipes.	Weight per running yard.			Present price per running foot.	
		C.	qrs.	lbs.	Dolls.	cts.
2 inch.	$\frac{4}{16}$ths.	0	1	2	0	40
3	full $\frac{4}{16}$ths.	0	1	16	0	51
4	$\frac{5}{16}$ths.	0	2	4	0	67
6	$\frac{6}{16}$ths.	1	0	0	1	06
8	$\frac{8}{16}$ths.	1	1	21	1	40
10	$\frac{9}{16}$ths.	2	0	8	2	00
12	$\frac{9}{16}$ths.	2	2	18	2	30
16	$\frac{10}{16}$ths.	3	2	0	3	75
20	$\frac{10}{16}$ths.	5	0	0	5	00

A table of the weight of cast-iron pipes, 12 inches long, in pounds avoirdupoise.

Diam. of Bore.	¼	⅜	½	¾	1	1¼	1½	1¾	2	Thick. of Metal.
1	3,05	5,85	7,35	12,9	19,7	....	....	....	....	
1½	4,28	6,9	10,6	16,6	24,4	....	....	....	....	
2	5,5	8,7	12,2	20,0	29,25	39,5	....	....	....	
2½	6,73	10,5	14,6	23,5	34,2	46,6	....	....	....	
3	7,95	12,5	17,1	27,4	39.	51,75	....	....	....	
3½	9,15	14,25	19,5	31.	43,9	58.	....	....	....	
4	10,4	16.	22.	34,7	48,8	64,75	80,5	....	....	
4½	11,62	17,9	24,4	38,3	53,7	70,5	87,5	...	....	
5	12,8	20.	26,8	42.	58,6	76,3	95,4	....	....	
5½	....	21,8	29,3	45,6	63,5	82,5	103.	. ..	....	
6	....	23,6	31,75	49,5	68,5	88,2	110.	133.	156.	
6½	. ..	25,4	34,2	52,8	73,2	94,6	117.	141.	166.	
7	....	27.	36,5	56,6	78.	101.	125.	150.	176.	
7½	....	28,8	39.	60,2	83.	107.	132.	158.	186.	
8	....	31.	41,4	64.	87,5	112,8	139.	166.	196.	
8½	....	....	43,8	67,5	92,4	119.	146.	175.	206.	
9	....	....	46,3	71,2	97,5	125.	154.	183.	216.	
9½	....	...	48,6	74,8	102,5	131.	161.	192.	226.	
10	....	....	51,1	78,5	107.	137.	169.	200.	236.	
10½	....	....	53,6	82,5	112,1	143.	176.	209.	246.	
11	....	....	56,2	86.	117.	149.	183.	217.	255.	
11½	....	....	58,5	89,5	122.	155.	191.	227.	265.	
12	....	....	61.	93,5	127.	161.	198.	235.	275.	
12½	....	. ..	[illegible],5	97,3	132.	167.	205.	243.	285.	
13	....	....	66.	101.	137.	173,5	212.	252.	294.	
13½	....	. ..	68.4	104,8	141,5	179.	219.	260.	304.	
14	...	....	71.	108,2	146.	185.	227.	269.	314.	
14½	....	....	73.4	112,3	151.	192.	234.	277.	324.	
15	....	....	75.8	115,7	156.	198.	242.	286.	334.	
15½	....	....	78.1	119.	161.	204.	250.	295.	344.	
16	....	....	80,7	123.	166.	211.	257.	303.	353.	
16½	....	....	83,1	126,5	170,5	217.	264.	312.	363.	
17	....	....	85,5	130.	175,5	223.	271.	322.	373.	
17½	....	....	87,8	133,5	180,5	229.	278.	330.	383.	
18	....	....	90,5	137.	185.	235.	285.	338.	393.	
18½	....	....	93.	140,5	190.	241.	293.	347.	402.	
19	....	....	95,5	144,8	195.	247.	300.	354.	412.	
19½	....	....	97,8	148,5	200.	253.	307.	363.	422.	
20	....	....	100.	152.	205.	259.	315.	372.	432.	
20½	. ..	...	102,5	156.	210.	265.	323.	381.	442.	
21	....	....	105.	159,5	215.	271.	330.	390.	452.	
21½	....	....	107,5	163.	220.	277.	337.	398.	461.	
22	....	....	110.	166,5	226.	283.	344.	408.	471.	

APPENDIX.

GEOMETRY.

Geometry is that branch of mathematics which treats of the description and properties of magnitudes in general.

Definitions or Explanations of Terms.

1. A *point* has neither length, breadth, nor thickness. From this definition it may easily be understood that a mathematical point cannot be seen nor felt; it can only be imagined. What is commonly called a point, as a small dot made with a pencil or pen, or the point of a needle, is not in reality a mathematical point; for however small such a dot may be, yet if it be examined with a magnifying glass, it will be found to be an irregular spot, of a very sensible length and breadth; and our not being able to measure its dimensions with the naked eye, arises only from its smallness. The same reasoning may be applied to every thing that is usually called a point; even the point of the finest needle appears like that of a poker when examined with the microscope.

2. A *line* is length, without breadth or thickness. What was said above of a point, is also applicable to the definition of a line. What is drawn upon a paper with a pencil or pen, is not in fact a line, but the representation of a line. For however fine you may make these representations, they will still have some breadth. But by the definition, a line has no breadth whatever, yet it is impossible to draw any thing so fine as to have no breadth. A line, therefore, can only be imagined. The ends of a line are points.

3. A *right line* is what is commonly called a *straight line*, or that tends every where the same way.

4. A *curve* is a line which continually changes its direction between its extreme points.

5. *Parallel* lines are such as always keep at the same distance from each other, and which, if prolonged ever so far, would never meet. *Fig.* 1.

6. An *angle* is the inclination or opening of two lines meeting in a point. *Fig.* 2.

7. The lines AB, and BC, which form the angle, are called the legs or sides; and the point B where they meet, is called the *vertex* of the angle, or the *angular point.* An angle is sometimes expressed by a letter placed at the vertex, as the angle B, *Fig.* 2; but most commonly by three letters, observing to place in the middle the letter at the vertex, and the other two at the end of each leg, as the angle ABC.

8. When one line stands upon another, so as not to lean more to one side than to another, both the angles which it makes with the other are called *right angles*, as the angles ABC and ABD, *Fig.* 3, and all right angles are equal to each other, being all equal to 90°; and the line AB is said to be *perpendicular* to CD.

Beginners are very apt to confound the terms *perpendicular*, and *plumb* or *vertical line*. A line is vertical when it is at right angles to the plane of the horizon, or level surface of the earth, or to the surface of water, which is always level. The sides of a house are vertical. But a line may be perpendicular to another, whether it stands upright or inclines to the ground, or even if it lies flat upon it, provided only that it makes the two angles formed by meeting with the other line equal to each other; as for instance, if the angles ABC and ABD be equal, the line AB is perpendicular to CD, whatever may be its position in other respects.

9. When one line, BE,(*Fig.* 3,) stands upon another, CD, so as to incline the angle, EBC, which is greater than a right angle, is called an *obtuse* angle; and that which is less than a right angle, is called an *acute* angle, as the angle EBD.

10. Two angles which have one leg in common, as the angles ABC, and ABE, are called *contiguous* angles, or *adjoining* angles; those which are produced by the crossing of two lines, as the angles EBD and CBF, formed by CD and EF, crossing each other, are called *opposite* or *vertical* angles.

11. A *figure* is a bounded space, and is either a *surface* or a *solid.*

12. A *superficies*, or *surface*, has length and breadth only. The extremities of a superficies are lines.

13. A *plane*, or *plane surface*, is that which is every where perfectly flat and even, or which will touch every part of a straight line, in whatever direction it may be laid upon it. The top of a marble slab, for instance, is an example of this, which a straight edge will touch in every point, so that you cannot see light any where between.

14. A *curved surface* is that which will not coincide with a straight line in any part. Curved surfaces may be either convex or concave.

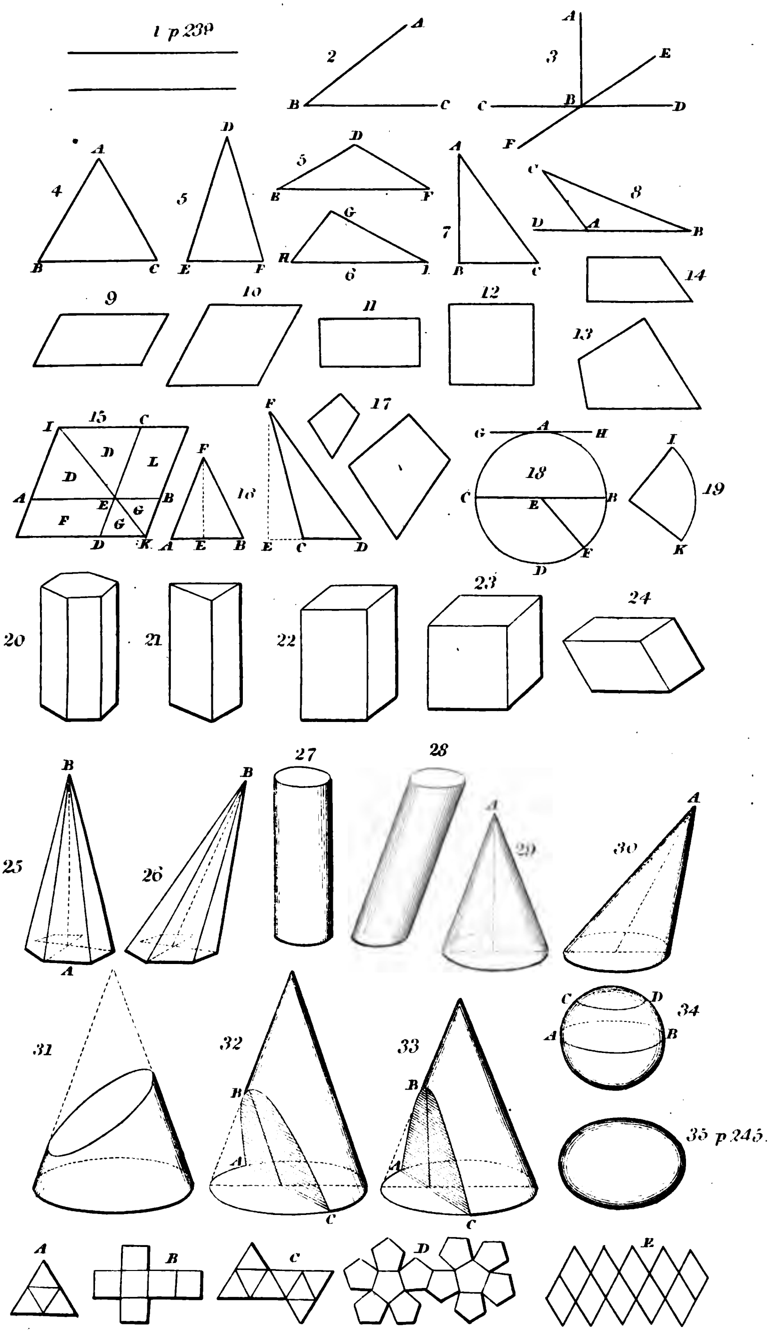
15. A *convex surface* is when the surface rises up in the middle, as, for instance, a part of the outside of a globe.

16. A *concave surface* is when it sinks in the middle, or is hollow, and is the contrary to convex.

A surface may be bounded either by straight lines, curved lines, or both these.

17. Every surface, bounded by straight lines only, is called a *polygon.* If the sides are equal, it is called a *regular polygon.* If they are unequal, it is called an *irregular polygon.* Every polygon, whether equal or unequal, has the same number of sides as angles, and they are denominated sometimes according to the number of sides, and sometimes from the number of angles they contain. Thus a figure of three sides is called a *triangle*, and a figure of four sides a *quadrangle.*

A *pentagon* is a polygon of five sides.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A *hexagon* has six sides.
A *heptagon* seven sides.
An *octagon* eight sides.
A *nonagon* nine sides.
A *decagon* ten sides.
An *undecagon* eleven sides.
A *duodecagon* twelve sides.

When they have a greater number of sides, it is usual to call them polygons of 13 sides, of 14 sides, and so on.

Triangles are of different kinds, according to the lengths of their sides.

18. An *equilateral triangle* has all its sides equal, as ABC, *Fig.* 4.

19. An *isosceles triangle* has two equal sides, as DEF, *Fig.* 5.

20. A *scalene triangle* has all its sides unequal, as GHI, *Fig.* 6.

Triangles are also denominated according to the angles they contain.

21. A *right-angled* triangle is one that has in it a right angle, as ABC, *Fig.* 7.

22. A triangle cannot have more than one right-angle. The side opposite to the right-angle B, as AC, is called the *hypothenuse*, and is always the longest side.

23. An *obtuse-angled* triangle has one obtuse-angle, as *Fig.* 8.

24. An *acute-angled* triangle has all its angles acute, as *Fig.* 4.

25. An isosceles, or a scalene triangle, may be either right-angled, obtuse, or acute.

26. Any side of a triangle is said to *subtend* the angle opposite to it: thus AB, (*Fig.* 7,) subtends the angle ACB.

27. If the side of a triangle be drawn out beyond the figure, as AD, (*Fig.* 8,) the angle A, or CAB, is called an *internal* angle, and the angle CAD, or that without the figure, an *external* angle.

28. A *quadrangle* is also called a *quadrilateral* figure. They are of various denominations, as their sides are equal or unequal, or as all their angles are right-angles or not.

29. Every four-sided figure whose opposite sides are parallel, is called a *parallelogram*. Provided that the sides opposite to each other be parallel, it is immaterial whether the angles are right or not. *Fig.* 9, 10, 11, and 12, are all parallelograms.

30. When the angles of a parallelogram are all right-angles, it is called a *rectangular parallelogram* or a *rectangle*, as *Fig.* 11 and 12.

31. A rectangle may have all its sides equal, or only the opposite sides equal. When all its sides are equal, it is called a *square*, as *Fig.* 12.

32. When the opposite sides are parallel, and all the sides equal to each other, but the angles not right angles, the parallelogram is called a *rhombus*, as *Fig.* 10.

33. A parallelogram having all its angles oblique, and only its opposite equal, is called a *rhomboid*, as *Fig.* 9.

34. When a quadrilateral or four-sided figure has none of its sides parallel, it is called a *trapezium*, as *Fig.* 13; consequently every

quadrangle, or quadrilateral which is not a parallelogram, is a trapezium.

35. A *trapezoid* has only one pair of its sides parallel, as *Fig.* 14.

36. A *diagonal* is a right line drawn between any two angles that are opposite in a polygon, as IK, *Fig.* 15. In parallelograms the diagonal is sometimes called the *diameter*, because it passes through the centre of the figure.

37. *Complements* of a parallelogram. If any point, as E, (*Fig.* 15,) be taken in the diagonal of a parallelogram, and through that point two lines are drawn parallel to the sides, as AB, CD, it will be divided into four parallelograms, DD, L, F, GG. The two divisions, L, F, through which the diameter does not pass, are called the complements.

38. *Base* of a figure is the side on which it is supposed to stand erect, as AB, and CD, *Fig.* 16.

39. *Altitude* of a figure is its perpendicular height from the base to the highest part, as EF, *Fig.* 16.

40. *Area* of a plane figure, or other surface, means the quantity of space contained within its boundaries, expressed in square feet, yards, or any other superficial measure.

41. *Similar figures* are such as have the same angles, and whose sides are in the same proportion, as *Fig.* 17.

42. *Equal* figures are such as have the same area or contents.

43. A *circle* is a plane figure, bounded by a curve line returning into itself, called its *circumference*, ABCD, (*Fig.* 18,) every where equally distant from a point E within the circle, which is called the *centre*.

44. The *radius* of a circle is a straight line drawn from the centre to the circumference, as EF, (*Fig.* 18.) The radius is the opening of the compass when a circle is described; and consequently all the radii of a circle must be equal to each other.

45. A *diameter* of a circle is a straight line drawn from one side of the circumference to the other through the centre, as CB, (*Fig.* 18.) Every diameter divides the circle into two equal parts.

46. A *segment* of a circle is a part of a circle cut off by a straight line drawn across it. This straight line is called the *chord*. A segment may be either equal to, greater, or less than a *semicircle*, which is a segment formed by the diameter of the circle, as CEB, and is equal to half the circle.

47. A *tangent* is a straight line, drawn so as just to touch a circle without cutting it, as GH, (*Fig.* 18.) The point A, where it touches the circle, is called the *point of contact*. And a tangent cannot touch a circle in more points than one.

48. A *sector* of a circle is a space comprehended between two radii and an arc, as BIK, (*Fig.* 19.)

49. The circumference of every circle, whether great or small, is supposed to be divided into 360 equal parts, called *degrees;* and every degree into 60 parts, called minutes; and every minute into 60 seconds. To measure the inclination of lines to each other, or

angles, a circle is described round the angular point, as a centre, as IK, *Fig.* 19; and according to the number of degrees, minutes, and seconds, cut off by the sides of the angle, so many degrees, minutes, and seconds, it is said to contain. Degrees are marked by °, minutes by ′, and seconds by ″; thus an angle of 48 degrees, 15 minutes, and 7 seconds, is written in this manner, 48° 15′ 7″.

50. A *solid* is any body that has length, breadth, and thickness: a book, for instance, is solid, so is a sheet of paper; for though its thickness is very small, yet it has some thickness. The boundaries of a solid are *surfaces.*

51. *Similar solids* are such as are bounded by an equal number of similar planes.

52. A *prism* is a solid, of which the sides are parallelograms, and the two ends or bases are similar polygons, parallel to each other. Prisms are denominated according to the number of angles in the base, *triangular* prisms, *quadrangular*, *heptangular*, and so on, as *Fig.* 20, 21, 22, 23. If the sides are perpendicular to the plane of the base, it is called an *upright* prism; if they are inclined, it is called an *oblique* prism.

53. When the base of a prism is a parallelogram, it is called a *parallelopipedon,* as *Fig.* 22 and 23. Hence, a parallelopipedon is a solid, terminated by six parallelograms.

54. When all the sides of a parallelopipedon are squares, the solid is called a *cube,* as *Fig.* 23.

55. A *rhomboid* is an oblique prism, whose bases are parallelograms. (*Fig.* 24.)

56. A *pyramid* AB, (*Fig.* 25 and 26,) is a solid, bounded by, or contained within, a number of planes, whose base may be any polygon, and whose faces are triangles terminated in one point, B, commonly called the *summit*, or *vertex* of the pyramid.

57. When the figure of the base is a triangle, it is called a *triangular pyramid;* when the figure of the base is a quadrilateral, it is called a *quadrilateral pyramid*, &c.

58. A pyramid is either *regular* or *irregular,* according as the base is regular or irregular.

59. A pyramid is also *right* or *upright,* or it is *oblique.* It is right, when a line drawn from the vertex to the centre of the base is perpendicular to it, as *Fig.* 25; and oblique, when this line inclines, as *Fig.* 26.

60. A *cylinder* is a solid, (*Fig.* 27 and 28,) generated or formed by the rotation of a rectangle about one of its sides, supposed to be at rest; this quiescent side is called the *axis* of the cylinder. Or it may be conceived to be generated by the motion of a circle, in a direction perpendicular to its surface, and always parallel to itself.

61. A cylinder is either *right* or *oblique,* as the axis is perpendicular to the base or inclined.

62. Every *section* of a right cylinder taken at right-angles to its axis, is a *circle;* and every section taken across the cylinder, but oblique to the axis, is an *ellipsis.*

63. A circle being a polygon of an infinite number of sides, it follows, that the cylinder may be conceived as a prism, having such polygons for bases.

64. A *cone* is a solid, (*Fig.* 29 and 30,) having a circle for its base, and its sides a convex surface, terminating in a point A, called the *vertex* or *apex* of the cone. It may be conceived to be generated by the revolution of a right-angled triangle about its perpendicular.

65. A line drawn from the vertex to the centre of the base is the *axis* of the cone.

66. When this line is perpendicular to the base, the cone is called an upright or *right* cone; but when it is inclined, it is called an *oblique* cone.

67. If it be cut through the axis, from the vertex to the base, the section will be a *triangle.*

68. If a right cone be cut by a plane at right-angles to the axis, the section will be a *circle.*

69. If it be cut oblique to the axis, and quite across from one side to the other, the section will be an *ellipsis*, as *Fig.* 31. A section of a cylinder, made in the same manner, is also an ellipsis; and this is easily conceived; but it does not appear so readily to most people, that the oblique section of a cone is an ellipsis: they frequently imagine that it will be wider at one end than the other, or what is called an *oval*, which is of the shape of an egg. But that this is a mistake, any one may convince himself, by making a cone, and cutting it across obliquely: it will then be seen, that the section, in whatever direction it is taken, is a regular ellipsis; and this is the case, whether the cone be right or oblique, except only in one case, in the oblique cone, which is, when the section is taken in a particular direction, which is called *sub-contrary* to its base.

70. When the section is made parallel to one of the sides of the cone, as *Fig.* 32, the curve ABC, which bounds the section, is called a *parabola.*

71. When the section is taken parallel to the axis, as *Fig.* 33, the curve is called an *hyperbola.*

These curves, which are formed by cutting a cone in different directions, have various properties, which are of great importance in astronomy, gunnery, perspective, and many other sciences.

72. A *sphere* is a solid, terminated by a convex surface, every point of which is at an equal distance from a point within, called the *centre*, *Fig.* 34.

73. It may be conceived to be formed by making a semicircle revolve round its diameter. This may be illustrated by the process of forming a ball of clay by the potter's wheel, a semicircular mould being used for the purpose. The diameter of the semicircle, round which it revolves, is called the *axis* of the sphere.

74. The ends of the axis are called *poles.*

75. Any line passing through the centre of the sphere, and terminated by the circumference, is a *diameter* of the sphere.

76. Every section of a sphere is a circle; every section taken

through the centre of the sphere, is called a *great circle*, as AB, *Fig.* 34; every other is a *lesser circle*, as CD.

77. Any portion of a sphere cut off by a plane, is called a *segment;* and when the plane passes through the centre, it divides the sphere into two equal parts, each of which is called a *hemisphere.*

78. A *conoid* is a solid, produced by the circumvolution of a section of the cone, about its axis, and, consequently, may be either an *elliptical conoid*, a *hyperbolical conoid*, or a *parabolical conoid.* When it is elliptical, it is generally called a *spheroid.* These solids are also called *ellipsoid*, *hyperboloid*, and *paraboloid.*

79. A *spheroid* is a solid, (*Fig.* 35,) generated by the rotation of a semi-ellipsis about the transverse or conjugate axis; and the centre of the ellipsis is the centre of the spheroid.

80. The line about which the ellipsis revolves, is called the *axis.* If the spheroid be generated about the conjugate axis of the semi-ellipsis, it is called a *prolate spheroid.*

81. If the spheroid be generated by the semi-ellipsis, by revolving about the transverse axis, it is called an *oblong spheroid.*

82. Every *section* of a spheroid is an *ellipsis*, except when it is perpendicular to that axis about which it is generated; in which case it is a circle.

83. All sections of a spheroid parallel to each other, are similar figures.

A *frustrum* of a solid, means a piece cut off from the solid, by a plane passed through it, usually parallel to the base of the solid, as the frustrum of a cone, a pyramid, &c.

There is a *lower* and an *upper* frustrum, according as the piece spoken of does or does not contain the base of the solid.

84. A regular body is a solid, contained under a certain number of equal and regular plane figures of the same sort.

85. The *faces of the solid* are the plane figures under which it is contained; and the *linear sides* or *edges of the solid*, are the sides of the plane faces.

86. There are only five regular bodies:—viz. 1st, the *tetraedon*, which is a regular pyramid, having four triangular faces; 2d, the *hexaedron*, or cube, which has six equal square faces; 3d, the *octaedron*, which has eight triangular faces; 4th, the *dodecaedron*, which has twelve pentagonal faces; 5th, the *icosaedron*, which has twenty triangular faces.

Note.—If the figures marked A, B, C, D, E, be exactly drawn on pasteboard, and the lines cut half through, so that the parts be turned up, and glued together, they will represent the five regular bodies, viz.—*Fig.* A, the tetraedon; B, the hexahedron; C, the octaedron; D, the dodecaedron; and E, the icosaedron.

87. *Ratio* is the proportion which one magnitude bears to another of the same kind, with respect to quantity, and is usually marked thus A : B.

Of these, the first is called the *antecedent*, and the second the *consequent.*

88. The *measure* or *quantity* of a ratio, is conceived by considering what part of the consequent is the antecedent; consequently, it is obtained by dividing the consequent by the antecedent.

89. *Three* magnitudes or quantities, A, B, C, are said to be *proportional*, when the ratio of the first to the second is the same as that of the second to the third. Thus, 2, 4, 8, are proportional, because 4 is contained in 8 as many times as 2 is in 4.

90. *Four* quantities, A, B, C, D, are said to be proportional, when the ratio of the first, A, to the second, B, is the same as the ratio of the third, C, to the fourth, D. It is usually written, $A : B :: C : D$, or, if expressed in numbers, $2 : 4 :: 8 : 16$.

91. Of *three* proportional quantities, the middle one is said to be a *mean proportional* between the other two; and the last a *third proportional* to the first and second.

92. Of *four* proportional quantities, the last is said to be a *fourth proportional* to the other three, taken in order.

93. *Ratio of equality* is that which equal numbers bear to each other.

94. *Inverse ratio* is when the antecedent is made the consequent, and the consequent the antecedent. Thus, if $1 : 2 :: 3 : 6$; then, *inversely*, $2 : 1 :: 6 : 3$.

95. *Alternate proportion* is when the antecedent is compared with antecedent, and consequent with consequent. Thus, if $2 : 1 :: 6 : 3$; then, by *alternation*, $2 : 6 :: 1 : 3$.

96. Proportion by *composition* is when the antecedent and consequent, taken as one quantity, are compared either with the consequent or with the antecedent. Thus, if $2 : 1 :: 6 : 3$; then, by *composition*, $2 + 1 : 1 :: 6 + 3 : 3$, and $2 + 1 : 2 :: 6 + 3 : 6$.

97. *Divided proportion* is when the difference of the antecedent and consequent is compared either with the consequent or with the antecedent. Thus, if $3 : 1 :: 12 : 4$; then, by *division*, $3 - 1 : 1 :: 12 - 4 : 4$, and $3 - 1 : 3 :: 12 - 4 : 12$.

98. *Continued proportion* is when the first is to the second as the second to the third; as the third to the fourth; as the fourth to the fifth; and so on.

99. *Compound ratio* is formed by the multiplication of several antecedents and the several consequents of ratios together, in the following manner:

If A be to B as 3 to 5, B to C as 5 to 8, and C to D as 8 to 6; then A will be D, as $\frac{3 \times 5 \times 8}{5 \times 8 \times 6} = \frac{120}{240} = \frac{1}{2}$; that is, $A : D :: 1 : 2$.

100 *Bisect*, means to divide any thing into two equal parts.

101. *Trisect*, is to divide any thing into three equal parts.

102. *Inscribe*, to draw one figure within another, so that all the angles of the inner figure touch either the angles, sides, or planes of the external figure.

103. *Circumscribe*, to draw a figure round another, so that either the angles, sides, or planes of the circumscribed figure touch all the angles of the figure within it.

104. *Rectangle under any two lines*, means a rectangle which has two of its sides equal to one of the lines, and two of them equal to the other. Also, the rectangle under AB, CD, means AB $\times$ CD.

105. *Scales of equal parts.* A scale of equal parts is only a straight line, divided into any number of equal parts, at pleasure. Each part may represent any measure you please, as an inch, a foot, a yard, &c. One of these is generally subdivided into parts of the next denomination, or into tenths or hundredths. Scales may be constructed in a variety of ways. The most usual manner is, to make an inch, or some aliquot part of an inch, to represent a foot; and then they are called inch scales, three-quarter inch scales, half-inch scales, quarter-inch scales, &c. They are usually drawn upon ivory or box-wood.

106. An *axiom* is a manifest truth, not requiring any demonstration.

107. *Postulates* are things required to be granted true, before we proceed to demonstrate a proposition.

108. A *proposition* is when something is either proposed to be done, or to be demonstrated, and is either a *problem* or a *theorem.*

109. A *problem* is when something is proposed to be done, as some figure to be drawn.

110. A *theorem* is when something is proposed to be demonstrated or proved.

111. A *lemma* is when a premise is demonstrated, in order to render the thing in hand the more easy.

112. A *corollary* is an inference drawn from the demonstration of some proposition.

113. A *scholium* is when some remark or observation is made upon something mentioned before.

114. The sign = denotes that the quantities betwixt which it stands are equal.

115. The sign + denotes that the quantity after it is to be added to that immediately before it.

116. The sign — denotes, that the quantity after it is to be taken away or subtracted from the quantity preceding it.

Geometrical Problems.

Prob. 1. To divide a given line AB into two equal parts.

From the points A and B, as centres, and with any opening of the compasses greater than half AB, describe arches, cutting each other in c and d. Draw the line c d; and the point E, where it cuts AB, will be the middle required.

Prob. 2. To raise a perpendicular to a given line A B, from a point given at C.

Case 1. When the given point is near the middle of the line, on each side of the point C. Take any two equal distances, C d and C e; from d and e, with any radius or opening of the compasses greater than C d or C e, describe two arcs cutting each other in f. Lastly, through the points f, C, draw the line f C, and it will be the perpendicular required.

Case 2. When the point is at or near the end of the line. Take any point d, above the line, and with the radius or distance d C, describe the arc e C f, cutting AB in e and C. Through the centre d, and the point e, draw the line e d f, cutting the arc e C f in f. Through the points f C, draw the line f C, and it will be the perpendicular required.

Prob. 3. From a given point f, let fall a perpendicular upon a given line AB.

From the point f, with any radius, describe the arc d e, cutting AB in e and d. From the points e d, with the same or any other radius, describe two arcs, cutting each other in g. Through the points f and g, draw the line f g, and f C will be the perpendicular required.

Prob. 4. To make an angle equal to another angle which is given, as a B b.

From the point B, with any radius, describe the arc a b, cutting the legs B a, B b, in the points a and b. Draw the line D e, and from the point D, with the same radius as before, describe the arc e f, cutting D e in e. Take the distance B a, and apply it to the arc e f, from e to f. Lastly, through the points D, f, draw the line D f, and the angle e D f will be equal to the angle b B a, as was required.

Prob. 5. To divide a given angle, ABC, into two equal angles.

From the point B, with any radius, describe the arc AC. From A and C, with the same, or any other radius, describe arcs cutting each in d. Draw the line B d, and it will bisect the angle ABC, as was required.

Prob. 6. To lay down an angle of any number of degrees.

There are various methods of doing this. One is by the use of an instrument called a *protractor*, with a semi-circle of brass, having its circumference divided into degrees. Let AB be a given line, and let it be required to draw from the angular point A, a line making, with AB, any number of degrees, suppose 20. Lay the straight side of the protractor along the line AB, and count 20° from the end B of the semicircle; at C, which is 20° from B, mark; then, removing the protractor, draw the line AC, which makes, with AB, the angle required. Or, it may be done by a divided line, usually drawn upon scales, called a *line of chords*. Take 60° from the line of chords, in the compasses, and setting one at the angular point B, *Prob.* 4, with that opening as a radius, describe an arch, as a b: then take the number of degrees of which you intend the angle to be, and set it from b to a, then is a B b the angle required.

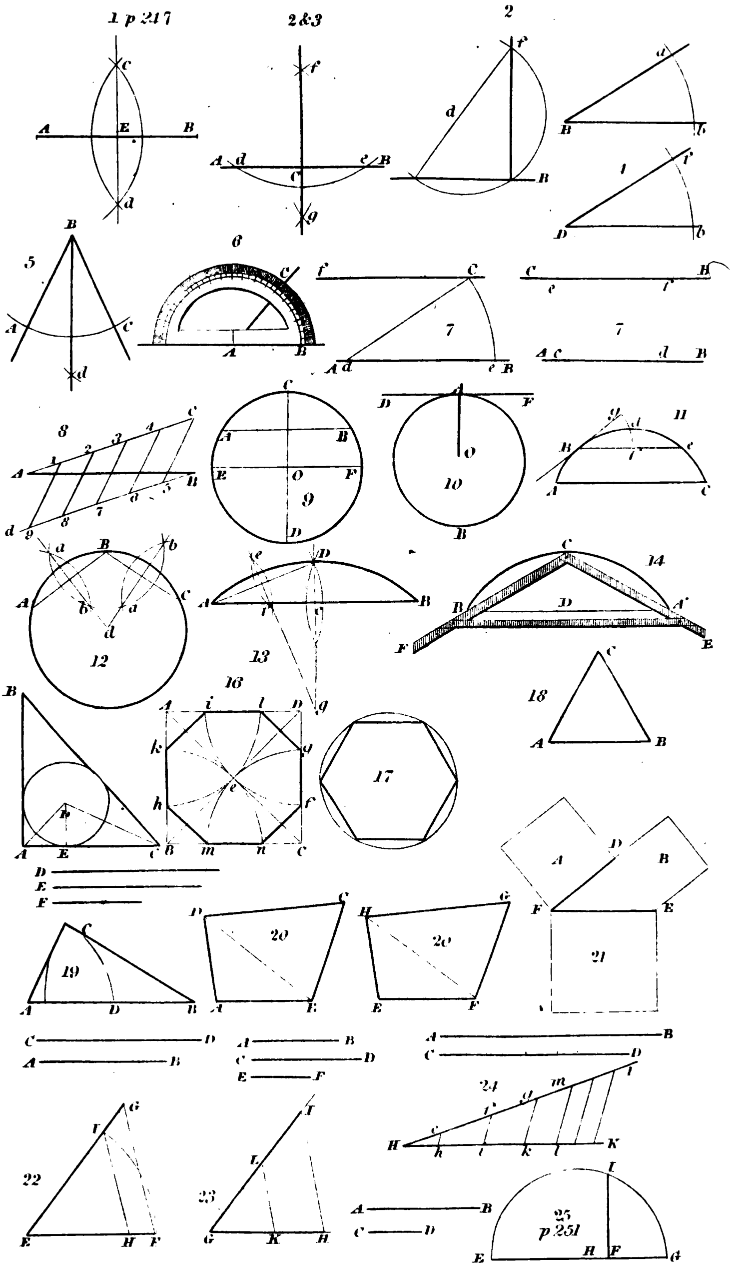
Prob. 7. Through a given point C, to draw a line parallel to a given line AB.

Case 1. Take any point d, in AB; upon d and C, with the distance C d, describe two arcs, e C, and d f, cutting the line AB in e and d. Make d f equal to e C; through C and f draw C f, and it will be the line required.

Case 2. When the parallel is to be at a given distance from AB. From any two points, c and d, in the line AB, with a radius equal to the given distance, describe the arcs e and f: draw the line CB to

GEOMETRY

Problems



touch those arcs without cutting them, and it will be parallel to AB, as was required.

Prob. 8. To divide a given line AB, into any proposed number of equal parts.

From A, one end of the line, draw A c, making any angle with AB; and from B, the other end, draw B d, making the angle A B d equal to B A c. In each of these lines, A c, B d, beginning at A and B, set off as many equal parts, of any length, as AB is to be divided into. Join the points C 5, 46, 57, and AB will be divided as required.

Prob. 9. To find the centre of a given circle, or of any one already described. Draw any chord AB, and bisect it with the perpendicular CD. Bisect CD with the diameter EF, and the intersection O will be the centre required.

Prob. 10. To draw a tangent to a given circle that shall pass through a given point, A.

From the centre O, draw the radius OA. Through the point A, draw DE perpendicular to OA, and it will be the tangent required.

Prob. 11. To draw a tangent to a circle, or any segment of a circle ABC, through a given point B, without making use of the centre of the circle.

Take any two equal divisions upon the circle, from the given point B, towards d and e, and draw the chord e B. Upon B, as a centre, with the distance B d, describe the arc f d g, cutting the chord e B in f. Make d g equal to d f; through g draw g B, and it will be the tangent required.

Prob. 12. Given three points, A, B, C, not in a straight line, to describe a circle that shall pass through them.

Bisect the lines AB, BC, by the perpendiculars a b, b d, meeting at d. Upon d, with the distance d A, d B, or d C, describe ABC, and it will be the required circle.

Prob. 13. To describe the segment of a circle to any length AB, and height CD.

Bisect AB by the perpendicular D g, cutting AB in c. From c make c D, on the perpendicular, equal to CD. Draw AD, and bisect it by a perpendicular e f, cutting D g in g. Upon g the centre, describe ADB, and it will be the required segment.

Prob. 14. To describe the segment of a circle by means of two rules, to any length AB, and perpendicular height CD in the middle of AB, without making use of the centre.

Place the rules to the height at C; bring the edges close to A and B; fix them together at C, and put another piece across them to keep them fast. Put in pins at A and B, then move the rulers round these pins, holding a pencil at the angular point C, which will describe the segment.

Prob. 15. In any given triangle to inscribe a circle.

Bisect any two angles A and C, with the lines AD and DB. From D, the point of intersection, let fall the perpendicular DE; it will be the radius of the circle required.

IC and PD, cutting each other at K; bisect KC by a perpendicular meeting CD in O; and on O, with the radius OC, describe the quadrant CGQ.

Through Q and A, draw QG, cutting the quadrant at G; then draw GO, cutting AB at M; make EL equal to EM, also EN equal to EO. From N, through M and L draw NH and NI; then M, L, N, O, are the four centres by which the four quarters of the ellipsis are drawn.

It must be observed, that this is not a true ellipsis, but only an approximation to it; for it is impossible to draw a perfect ellipsis by means of compasses, which can only describe parts of circles. But the curve of an ellipsis differs essentially from that of a circle in every part; and no portions of circles put together, can ever form an ellipsis. But by this means, a figure may be drawn, which approaches nearly to an ellipsis, and therefore may be often substituted for it when a trammel cannot be had, or when the ellipsis is too small to be drawn by it. At the joining of the portions of circles in this operation, the defect is not perceivable; and the best way is not to join them quite, and to help the curve by hand.

Prob. 29. An ellipsis, ACDB, being given, to find the transverse and conjugate axis.

Draw any two parallel lines, AB and CD, cutting the ellipsis at the points A, B, C, D; bisect them in e and f. Through e and f, draw GH, cutting the ellipsis at G and H; bisect GH at I; and it will give the centre.

Upon I, with any radius, describe a circle, cutting the ellipsis in the four points k, l, m, n; join k, l, and m, n; bisect k l, or m n, at o or p. Through the points o, I, or I, p, draw QR, cutting the ellipsis at Q and R; then QR will be the transverse axis. Through I draw TS, parallel to k l, cutting the ellipsis at T and S; and TS will be the conjugate axis.

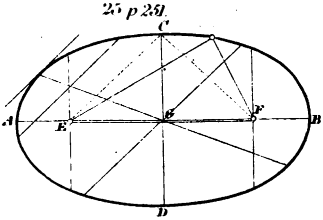
Prob. 30. To describe an ellipsis similar to a given one ADBC, to any given length IK, or to a given width ML.

Let AB and CD be the two axes of the given ellipsis. Through the points of contact A, D, B, C, complete the rectangle GEHF; draw the diagonals EF and GH: they will pass through the centre at R. Through I and K draw PN and OQ parallel to CD, cutting the diagonals EF and GH, at P, N, Q, O. Join PO and NQ, cutting CD at L and M; then IK is the transverse, and ML the conjugate axis of an ellipsis, that will be similar to the given ellipsis ADBC, which may be described by some of the foregoing methods.

Prob. 31. To describe a parabola. If a thread equal in length to BC, be fixt at C, the end of a square ABC, and the other end be fixt at F; and if the side AB of the square be moved along the line AD, and if the point E be always kept close to the edge BC of the square, keeping the string tight, the point or pin E will describe a curve EGIH, called a *parabola*.

The *focus* of the parabola is the fixed point F, about which the string revolves.

25 p 251.



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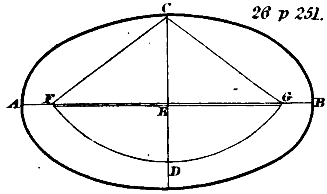

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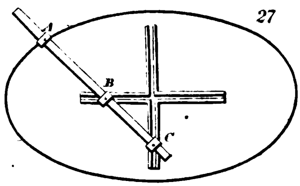

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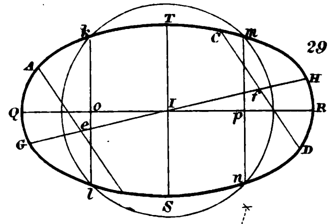

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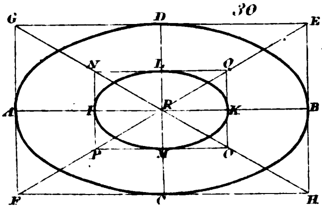

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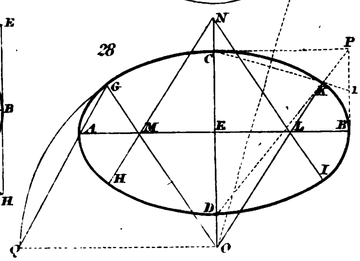

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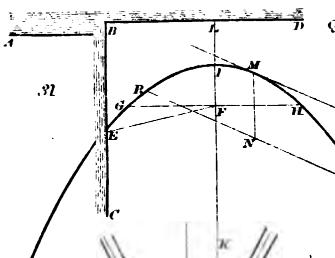

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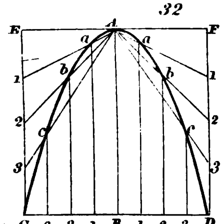

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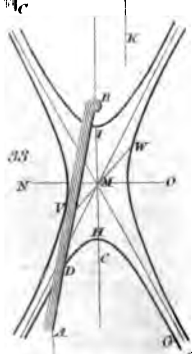
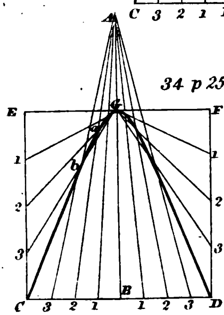
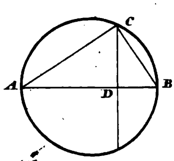


34 p 254





The *directrix* is the line AD, which the side of the square moves along.

The *axis* is the line LK, drawn through the focus F, perpendicular to the directrix.

The *vertex* is the point I, where the line LK cuts the curve.

The *latus rectum*, or *parameter*, is the line GH passing through the focus F, at right angles to the axis IK, and terminated by the curve.

The *diameter* is any line MN, drawn parallel to the axis IK.

A *double ordinate* is a right line RS, drawn parallel to a tangent at M, the extreme of the diameter MN, terminated by the curve.

The *abscissa* is that part of a diameter contained between the curve and its ordinate, as MN.

Prob. 32. To describe a *parabola*, by finding points in the curve; the axis AB, or any diameter being given, and a double ordinate CD.

Through A draw EF parallel to CD; through C and D draw DF and CE parallel to AB, cutting EF at E and F. Divide BC and BD, each into any number of equal parts, as four; likewise divide CE and DF into the same number of equal parts. Through the points 1, 2, 3, &c. in CD, draw the lines 1 a, 2 b, 3 c, &c. parallel to CD; also through the points 1, 2, 3, in CE and DF, draw the lines 1 A, 2 A, 3 A, cutting the parallel lines at the points a, b, c; then the points a, b, c, are in the curve of the parabola.

Prob. 33. To describe an *hyperbola*.

If B and C are two fixed points, and a rule AB be made movable about the point B, a string ADC being tied to the other end of the rule, and to the point C; and if the point A be moved round the centre B, towards G, the angle D of the string ADC, by keeping it always tight and close to the edge of the rule AB, will describe a curve DHG, called an hyperbola.

If the end of the rule at B were made movable about the point C, the string being tied from the end of the rule A to B, and a curve being described after the same manner, is called an *opposite hyperbola*.

The *foci* are the two points B and C, about which the rule and string revolves.

The *transverse axis* is the line IH terminated by the two curves passing through the foci, if continued.

The *centre* is the point M, in the middle of the transverse axis IH.

The *conjugate axis* is the line NO, passing through the centre M, and terminated by a circle from H, whose radius is M C, at N and O.

A *diameter* is any line VW, drawn through the centre M, and terminated by the opposite curves.

Conjugate diameter to another, is a line drawn through the centre, parallel to a tangent with either of the curves, at the extreme of the other diameter terminated by the curves.

Abscissa is when any diameter is continued within the curve, terminated by a double ordinate and the curve; then the part within is called the abscissa.

Double ordinate is a line drawn through any diameter parallel to its conjugate, and terminated by the curve.

Parameter or *latus rectum*, is a line drawn through the focus, perpendicular to the transverse axis, and terminated by the curve.

Prob. 34. To describe an hyperbola by finding points in the curve, having the diameter or axis AB, its abscissa BG, and the double ordinate DC.

Through G draw EF, parallel to CD; from C and D draw CE and DF, parallel to BG, cutting EF in E and F. Divide CD and BD, each into any number of equal parts, as four; through the points of division, 1, 2, 3, draw lines to A. Likewise divide EC and DF into the same number of equal parts, viz. four; from the divisions on CE and DF, draw lines to G; a curve being drawn through the intersections at G, a, b, &c. will be the hyperbola required.

Remarks.—In a circle, the half chord DC, is a mean proportional between the segments AD, DB of the diameter AB perpendicular to it. That is AD : DC : : DC : DB.

2. The chord AC is a mean proportional between AD and the diameter AB. And the chord BC a mean proportional between DB and AB.

That is, AD : AC : : AC : AB,
and BD : BC : : BC : AB.

3. The angle ACB, in a semicircle, is always a right.

4. The square of the hypotenuse of a right-angled triangle, is equal to the squares of both the sides.

That is, $AC^2 = AD^2 + DC^2$,
and $BC^2 = BD^2 + DC^2$,
and $AB^2 = AC^2 + BC^2$.

5. Triangles that have all the three angles of the one respectively equal to all the three of the other, are called equiangular triangles, or similar triangles.

6. In similar triangles, the like sides, or sides opposite the equal angles, are proportional.

7. The areas, or spaces, of similar triangles, are to each other, as the squares of their like sides.

MENSURATION OF SUPERFICIES.

Prob. 1. To find the area of a parallelogram: whether it be a square, a rectangle, a rhombus, or a rhomboid.

Multiply the length by the breadth, or perpendicular height, and the product will be the area.

Ex. 1. To find the area of a square, whose side is six inches, or 6 feet, &c.

6
6
—
Ansr. 36

2. To find the area of a rectangle, whose length is 9, and breadth 4 inches, or feet, &c.

```
        9
        4
       ——
  Ansr. 36
       ——
```

3. To find the area of a rhombus, whose length is 6 chains, and perpendicular height 5.

```
        6
        5
       ——
  Ansr. 30
       ——
```

Prob. 2. To find the Area of a Triangle.

Rule 1. Multiply the base by the perpendicular height, and half the product will be the area.

Rule 2. When the three sides only are given: Add the three sides together, and take half the sum; from the half sum subtract each side separately; multiply the half sum and the three remainders continually together; and the square root of the last product will be the area of the triangle.

Ex. Required the area of the triangle whose base is six feet, and perpendicular height 5 feet.

```
        6
        5
       ——
  2) 30 (15 Ansr.
```

Prob. 3. To find one Side of a right-angled Triangle, having the other two Sides given.

The square of the hypotenuse is equal to both the squares of the two legs. Therefore,

1. To find the hypotenuse; add the squares of the two legs together, and extract the square root of the sum.

2. To find one leg; subtract the square of the other leg from the square of the hypotenuse, and extract the root of the difference.

Ex. 1. Required the hypotenuse of a right-angled triangle, whose base AB is 40, and perpendicular BC 30.

```
 4   3
 4   3
——  ——
16   9
 9
——
25  (5 the square root of the sum of the two squares, being
25       the hypotenuse AC.
——
```

2. What is the perpendicular of a right-angled triangle, whose base AB is 56, and hypotenuse, AC 65?

```
 56     65
 56     65
----   ----
 336    325
280    390
----   ----
3136   4225
       3136
       ----
       1089 (33
       9
     -------
  63 | 189
   3 | 189
```

The perpendicular, which is the root of the remainder of the square of the hypotenuse AC, when the square of AB has been subtracted.

Prob. 4. To find the Area of a Trapezoid.

Multiply the sum of the two parallel sides by the perpendicular distance between them, and half the product will be the area.

Ex. In a trapezoid, the parallel sides are AB 7, and C D 12, and the perpendicular distance AP or CN is 9: required the area.

```
  7
 12
---
 19
  9
---
171
---
```

$85\frac{1}{2}$ the area.

Prob. To find the Area of a Trapezium.

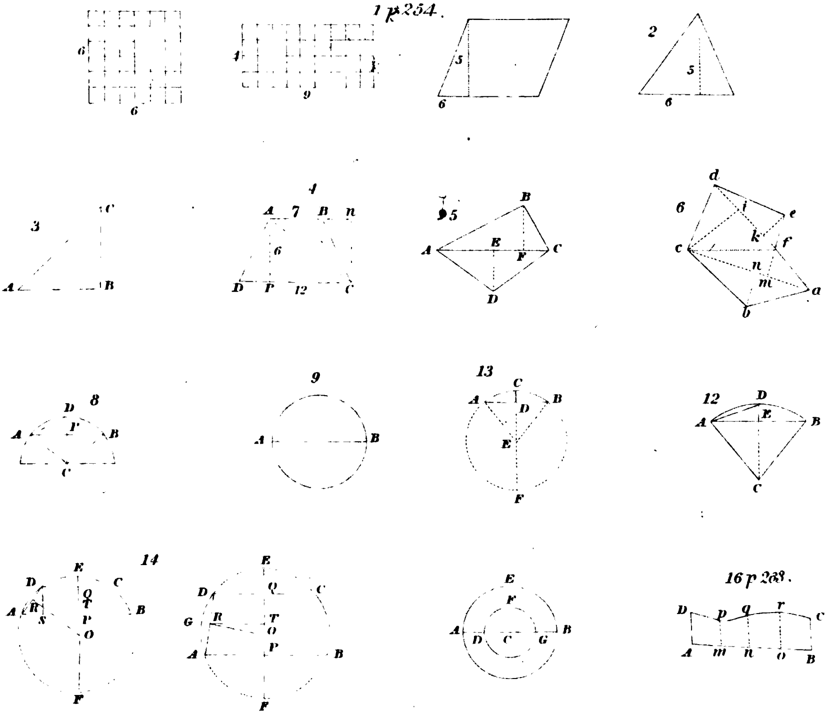
Case for any trapezium.—Divide it into two triangles by a diagonal; then find the areas of these triangles, and add them together.

Note. If two perpendiculars be let fall on the diagonal, from the other two opposite angles, the sum of these perpendiculars being multiplied by the diagonal, half the product will be the area of the trapezium.

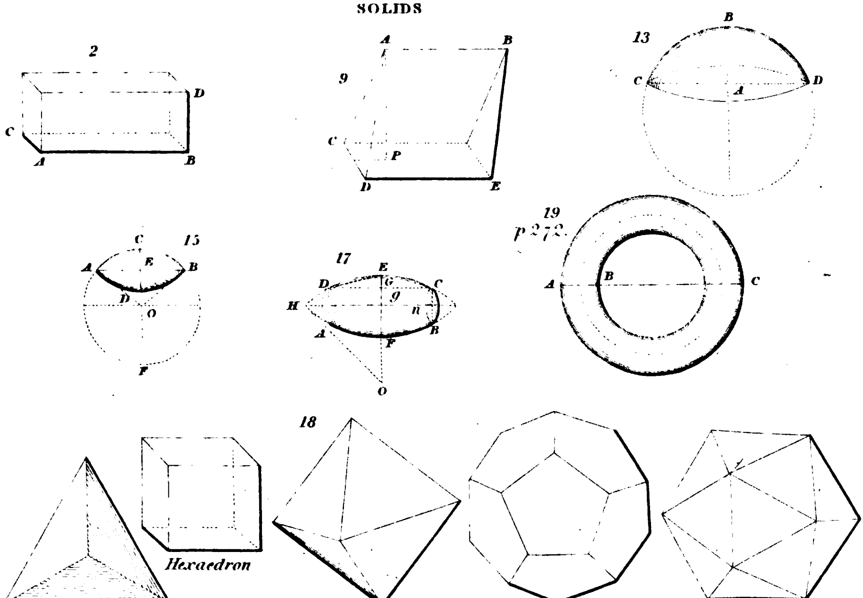
Ex. To find the area of the trapezium ABCD, the diagonal AC being 42, the perpendicular BF 18, and the perpendicular DE 16.

```
     18
     16
   ----
     34
     42
   ----
     68
    136
2) 1428
    714 the answer.
```

Superficies



SOLIDS



Hexaedron

Tetraedon

Octaedron

Dodecaedron

Icosaedron

Prob. 6. To find the Area of an Irregular Polygon.

Draw diagonals dividing the figure into trapeziums and triangles. Then find the areas of all these separately, and their sum will be the content of the whole irregular figure.

Ex. To find the content of the irregular figure ABCDEF, in which are given the following diagonals and perpendiculars: namely,

c.a = 10
d.f = 6
c.i = 4
k.e = 2
m.f = 3
n.b = 4

For trapez. d c f e.		For trapez. c f a b	
ci.	4	n.b.	4
ke.	2	m.f.	3
	6		7
df.	6	c.a.	10
	2) 36		2) 70
	18 contents.		35 contents.

18 contents d. c. f e
35 —— c. f. a b

53 contents of the irregular polygon.

Prob. 7. To find the Area of a Regular Polygon.

Rule. Multiply the perimeter of the figure, or sum of its sides, by the perpendicular falling from its centre upon one of its sides, and half the product will be the area.

Prob. 8. In a Circular Arc, having any two of the following lines, viz. the chord AB, the versed sine DP, the chord of half the arc AD, and the diameter, or the radius AC or CD given to find the others.

If any two of these lines be given, two sides of one of the right-angled triangles, APC or APD, will be known, and from them the remaining side, and other lines in the arc, may be found by Prob. 3.

Suppose AB and PD be given, then, by Prob. 3, the half of AB, or AP is a mean proportional between DP and PC + CD; for PC + CD + PD is the diameter of the circle, half of which is the radius or CA, and by Prob. 3, $AC^2 - AP^2 = CP^2$, and $AP^2 + PD^2 = AD^2$.

Suppose CD and AB be given, then half of AB = AP, and CD = AC; therefore $\sqrt{CD^2 - AP^2} = CP$, and CD − CP = PD. $\sqrt{PD^2 + AP^2}$ AD.

Prob. 9. To find the diameter and Circumference of a Circle, the one from the other.

Rule 1. As 7 is to 22, so is the diameter to the circumference.
As 22 is to 7, so is the circumference to the diameter.

Rule 2. As 113 is to 355, so is the diameter to the circumference.
As 355 is to 113, so is the circumference to the diameter.

Rule 3. As 1 is to 3.1416, so is the diameter to the circumference.
As 3.1416 is to 1, so is the circumference to the diameter.

Ex. 1. To find the circumference of a circle, whose diameter AB is 10.

By Rule 1.

7 : 22 : : 10 : 31.42857
10

7) 220
$31\frac{3}{7}$
or 31.42857 ans.

By Rule 2.

113 : 355 : : 10 : $31\frac{47}{113}$
10

113) 3550 (31.41593 the ans.
160
470
180
670
1050
330.

By Rule 3.

1 : 3.1416 : : 10 : 31.416 the circumference nearly, the true circumference being 31.4159265358979, &c.

So that the 2d rule is nearest the truth.

2. To find the diameter when the circumference is 100.

By Rule 1.

$$22 : 7 : : 50 : \frac{7 \times 25}{11} = \frac{175}{11} = 15\tfrac{10}{11} = 15.9\dot{0}9\dot{0} \text{ ans.}$$

By Rule 2.

$355 : 113 :: 50 : 15\frac{65}{71}$

```
        50
      ------
355 | 5650
      ------
 71 | 1130(15.9155
      ------
       420
      ------
       650
       ------
        110
       ------
        390
        ------
         350
        ------
```

By Rule 3.

$3.1416 : 1 :: 50 : 15.9156$

```
            50
         -------
3.1416)50.000(15.9156
         -------
.......) 18584
         -------
          2876
          -----
            49
            --
            18
            --
             2
            --
```

Prob. 10. To find the Length of any Arc of a Circle.

Rule 1. As 180 is to the number of degrees in the arc,
So is 3.1416 times the radius, to its length.
Or as 3 is to the number of degrees in the arc,
So is .05236 times the radius, to its length.

Ex. 1. To find the length of an arc ADB, (Prob. 8,) of 30 degrees, the radius being 9 feet.

```
                3.1416
                     9
As 180 : 30 ---------
Or 6 : 1 : : 282744 : 4.7124
Or 3 : 30 : : .05236 × 9 : 4.7124
                    90
                -------
                4.7124 the answer.
                -------
```

Rule 2. From 8 times the chord of half the arc subtract the chord of the whole arc, and $\frac{1}{3}$ of the remainder will be the length of the arc nearly.

Ex. 2. The chord AB, (*Prob.* 8,) of the whole arc being 4.65874, and the chord AD of the half arc 2.34947; required the length of the arc.

```
    2.34947
          8
   --------
   18.79576
    4.65874
   --------
3) 14.13702
   --------
    4.71234 answer.
```

Prob. 11. To find the Area of a Circle, the diameter or circumference being given.

Rule 1. Multiply half the circumference by half the diameter. Or take $\frac{1}{4}$ of the product of the whole circumference and diameter.

Rule 2. Multiply the square of the diameter by .7854.

Rule 3. Multiply the square of the circumference by .07958.

Rule 4. As 14 is to 11, so is the square of the diameter to the area.

Rule 5. As 88 is to 7, so is the square of the circumference to the area.

Ex. To find the area of a circle whose diameter is 10, and circumference 314.159265.

By Rule 1.

```
    31.4159265
            10
   -----------
 4)314.159265
   -----------
area 78.539816
```

By Rule 2

```
      .7854
        100
     ------
area  78.54
```

By Rule 4.

```
14 : 11 :: 100
            11 area
          ----
14 |      1100 | 78.57
   |        98 |
          ----
           120
           112
          ----
            80
            70
          ----
           100
            98
          ----
             2
```

By Rule 3.

```
sq. circ. 986.96044
invert        85970
          ---------
            6908723
             888264
              49348
               7896
          ---------
           78.54231 area.
          ---------
```

By Rule 5.

```
31.4159265 circum.
562951413 invert.
---------
 94247779
  3141593
  1256637
    31416
    15708
     2827
       63
       19
        2
---------
88 : 7 :: 986.96044
                  7
         ----------
      8 | 6908.72308
         ----------
     11 |  863.59038
         ----------
            78.50821
```

Prob. 12. To find the Area of the Sector of a Circle.

Rule 1. Multiply the radius, or half the diameter, by half the arc of the sector, for the area. Or take $\frac{1}{4}$ of the product of the diameter and arc of the sector.

Note. The arc may be found by problem 10.

Rule 2. As 360 is to the degrees in the arc of the sector, so is the whole area of the circle, to the area of the sector.

Ex. What is the area of the sector CAB, the radius being 10, and the chord AB 16.

$100 = AC^2$
$64 = AE^2$

$36\ (6 = CE$
$10 = CD$

$4 = DE$

$16 = DE^2$
$64 = AE^2$

$80\ (8.9442719 = AD.$
8

71.5541752
16

$3)\ 55.5541752$

$2)\ 18.5180584$ arc ADB

$9.2590297 =$ half arc
$10 =$ radius

92.590297 answer.

Prob. 13. To find the Area of a Segment of a Circle.

Rule. Find the area of the sector having the same arc with the segment, by the last problem.

Find the area of the triangle, formed by the chord of the segment and the two radii of the sector.

Then the sum of these two will be the answer when the segment is greater than a semicircle: but the difference will be the answer when it is less than a semicircle.

Ex. Required the area of the segment ACBD, its chord AB being 12, and the radius EA or CE 10.

100 AE^2
36 AD^2

64 DE^2

its root 8 DE
from 10 CE

2 CD

4 CD^2
36 AD^2

40 chord AC^2

its root 6.324555 chord AC
8

50.596440
12.

3)38.59644

2)12.86548 arc ACB

6.43274 ½ arc
10 radius

64.3274 area of sect. EACB
48.0000 area of triangle EAB

ans. 16.3274 area of segm. ACBA

6 AD
8 DE

48 area of △ EAB

Prob. 14. To find the Area of a Circular Zone ADCBA.

Rule. 1. Find the areas of the two segments AEB, DEC, and their difference will be the zone ADCB.

Rule 2. To the area of the trapezoid DQP add the area of the small segment ADR; and double the sum for the area of the zone ADCB.

Prob. 15. To find the Area of a circular Ring, or Space included between two Concentric Circles.

The difference between the two circles will be the ring. Or, multiply the sum of the diameters by their difference, and multiply the product by .7854 for the answer.

Ex. The diameters of the two concentric circles being AB 10

and DG 6, required the area of the ring contained between their circumferences AEBA, and BFGD.

	10	.7854
	6	64
sum.	16	31416
dif.	4	47124
	64	50.2656 Ansr.

Prob. 16. To measure long Irregular Figures.

Take the breadth in several places at equal distances. Add all the breadths together, and divide the sum by the number of them, for the mean breadth; which multiply by the length for the area.

Ex. The breadths of an irregular figure, at five equi-distant places being AD 8.1, mP 7.4, nq 9.2, or 10.1, BC 8.6; and the length AB 39; required the area.

```
    8.1
    7.4
    9.2
   10.1
    8.6
   ----
5) 43.4
   ----
   8.68
     39
   ----
   7812
  2604
  ----
  338.52 Ansr.
```

MENSURATION OF SOLIDS.

Prob. 1. To find the solidity of a Cube.

Cube one of its sides for the contents; that is, multiply the side by itself, and that product by the side again.

Ex. If the side of a cube be 24 inches, what is its solidity or contents?

```
   24
   24
  ---
   96
  48
  ---
  576
   24
 ----
 2304
1152
-----
13824 Ansr.
```

Prob. 2. To find the solidity of a Parallelopipedon.

Multiply the length by the breadth, and the products by the depth or altitude.

Ex. Required the contents of the pàrallelopipedon whose length AB is 6, its breadth AC 2, and altitude BD 3.

```
 6
 2
--
12
 3
--
36 Ansr.
```

Prob. 3. To find the Solidity of any Prism.

Multiply the area of the base, or end, by the height, and it will give the contents.

Which rule will do, whether the prism be triangular or square, or pentagonal, &c. or round, as a cylinder.

Ex. What is the content of a triangular prism, whose length is 12, and each side of its equilateral base 8?

Area of base 28 × 12 = 336 contents.

Prob. 4. To find the Convex Surface of a Cylinder.

Multiply the circumference by the height of the cylinder.

Prob. 5. To find the Convex Surface of a Right Cone.

Multiply the circumference of the base by the slant height, or length of the side, and half the product will be the surface.

Ex. If the diameter of the base be 5 feet, and the side of the cone 18, required the convex surface.

```
    3.1416
         5
   -------
   15.7080 circumf.
        18
   -------
    125664
    15708
   -------
2) 282.744
   -------
   141.372 Ansr.
```

Prob. 6. To find the Convex surface of the Frustum of a Right Cone.

Multiply the sum of the perimeters of the two ends by the slant height or side of the frustum, and half the product will be the surface.

Ex. If the circumferences of the two ends be 12.5 and 10.3, and the slant height 14, required the convex surface of the frustum.

12.5
10.3
——
22.8
14
——
912
228
——
2)319.2
——
159.6 Ansr.

Prob. 7. To find the Solidity of a Cone, or any Pyramid.

Multiply the area of the base by the perpendicular height of the area, and one-third of the product will be the contents.

Prob 8. To find the Solidity of any Frustum of a Cone or Pyramid.

Rule. Add together the area of the base, the area of the upper surface, and the mean proportional between those areas; take one-third of this sum for the mean area, which multiplied by the height will give the contents.—Or, for a cone, take the square of each diameter of the base and upper surface, and the product of these two diameters multiplied together; add these three sums together, and multiply by .2618 for the mean area, which multiply as before.

Or, if the circumferences be used in like manner, instead of their diameters, the multiplier will be .02654.

Ex. What is the content of the frustum of a cone, whose height is 20 inches, and the diameters of its two ends 28 and 20 inches?

Area of base	615.79	28	28	20
Area of upper surface	314.16	28	20	20
Mean proportional	439.84			
		224	560	400
	3) 1369.79	56	784	
			400	
	456.59	784		
	20		1744	
			2618	
	9131.80			
			13952	
			1744	
			10464	
			3488	
			456.5792	
			20	
			9131.5840 Ansr.	

Prob. 9. To find the Solidity of a Wedge.

To the length of the edge add twice the length of the back or base, and reserve the sum; multiply the height of the wedge by the breadth of the base; then multiply this product by the reserved sum, and one-sixth of the last product will be the contents.

Ex. What is the contents of a wedge, whose altitude AP is 14 inches; its edge AB 21 inches, and the length of its base DE 32 inches, and its breadth CD $4\frac{1}{2}$ inches?

```
 21      14
 32      4½
 32      ——
 ——      56
 85       7
 ——      ——
         63
         85
        ———
        315
       504
       ———
   6 | 5355
     |  892.5 Ansr.
```

Prob. 10. To find the Solidity of a Prismoid.

Definition.—A prismoid differs only from the frustum of a pyramid, in not having its opposite ends similar planes.

Rule. Add into one sum, the areas of the two ends and four times the middle section parallel to them, and one-sixth of that sum will be a mean area; and being multiplied by the height, will give the contents.

Note.—The length of the middle section is equal to half the sum of the lengths of the two ends; and its breadth is equal to half the sum of the breadths of the two ends.

Ex. What are the contents of a prismoid whose ends are rectangles, the length and breadth of the one being 14 and 12; and the corresponding sides of the other 6 and 4, the perpendicular height being $30\frac{1}{2}$?

```
  14      10      6
  12       8      4
 ———      ——     ——
 168      80     24
 ———       4     ——
         ———
         320
         168
          24
         ———
     6 ) 512
```

$85\frac{1}{3}$ mean area.
$30\frac{1}{2}$ height

2560
$42\frac{2}{3}$

2602.6 Ansr.

Prob. 11. To find the Convex surface of a Sphere or Globe.

Multiply its diameter by its circumference.

Note.—In like manner the convex surface of any zone or segment is found, by multiplying its height by the whole circumference of the sphere.

Ex. Required the convex superficies of a globe, whose diameter or axis is 24.

3.1416
24 diam.

125664
62832

75.3984 circumf.
24

3015936
1507968

1809.5616 Ansr.

Prob. 12. To find the Solidity of a Sphere or Globe.

Multiply the cube of the axis by .5236.

Ex. What is the solidity of the sphere, whose axis is 12?

12
12

144
12

1728
.5236

10368
5184
3456
8640

904.7808 Ansr.

Prob. 13. To find the Solidity of a Spherical Segment.

To 3 times the square of the radius of its base add the square of its height; then multiply the sum by the height, and the product again by .5236.

Ex. Required the contents of a spherical segment, its height AB being 4, and the radius of its base CD 8.

8	4	.5236
8	4	832
64	16	10472
3	192	15708
		41888
192	208	
	4	435.6352 Ansr.
	832	

Prob. 14. To find the Solidity of a Spherical Zone or Frustum.

Add together the square of the radius of each end and $\frac{1}{3}$ of the square of their distance, or the height; then multiply the sum by the said height, and the product again by 1.5708.

Ex. What is the solid contents of a zone, whose greater diameter is 12, the less 8, and the height 10 inches?

6	4	10
6	4	10
36	16	3) 100
	36	
	$33\frac{1}{3}$	$33\frac{1}{3}$
	$85\frac{1}{3}$	
	1.5708	
	78540	
	125664	
	5236	
	134.0416	
	10	
	1340.416 Ansr.	

Prob. 15. To find the Surface of a Circular Spindle.

Multiply the length AB of the spindle by the radius OC of the involving arc. Multiply also the said arc ACB by the central distance OE, or distance between the centre of the spindle and centre of the revolving arc. Subtract the latter product from the former, and multiply the remainder by 6.2832, for the surface.

Note. The same rule will serve for any segment or zone cut off perpendicular to the chord of the revolving arc, only using the par-

ticular length of the part, and the part of the arc which describes it, instead of the whole length and whole arc.

Ex. Required the surface of a circular spindle, whose length AB is 40, and its thickness CD 30 inches.

Here, by the remarks at pa. 254.

The chord $AC = \sqrt{AE^2 + CE^2} = \sqrt{20^2 + 15^2} = 25$,
and $2\ CE : AC :: AC : CO = \frac{25^2}{30} = 20\frac{5}{6}$,
hence $OE = OC - CE = 20\frac{5}{6} - 15 = 5\frac{5}{6}$.

Also, by problem 10, rule 2, pa. 259.

25 AC
8

200
40 AB

3) 160
$53\frac{1}{3}$ arc ACB

Then, by our rule,

$20\frac{5}{6}$	$53\frac{1}{3}$
40	$5\frac{5}{6}$
800	$266\frac{2}{3}$
$33\frac{1}{3}$	$44\frac{4}{9}$
$833\frac{1}{3}$	$311\frac{1}{9}$
$311\frac{1}{9}$	

$522\frac{2}{9}$ or 522.2 or $\frac{4700}{9}$

6.2832	Or thus,
	6.2832
10444	4700
156666	
4177777	439824
10444444	251328
313333333	
	9) 29531.04
3281.22666	
	3281.226 ans. nearly.

Prob. 16. To find the Solidity of a Circular Spindle.

Multiply the central distance OE by half the area of the revolving segment ACBEA. Subtract the product from $\frac{1}{3}$ of the cube of EA, half the length of the spindle. Then multiply the remainder by 12.5664, or 4 times 3.1416, for the whole contents.

Ex. Required the contents of the circular spindle, whose length AB is 40, and middle diameter CD 30.

By the work of the last problem,

we have OE $= 6\frac{5}{6}$
and arc AC $= 26\frac{2}{3}$
and rad. OC $= 20\frac{5}{6}$

$533\frac{1}{3}$
$22\frac{2}{9}$

Sector OACB $555\frac{5}{9}$
AE × OE = OAB $116\frac{2}{3}$

2) $438\frac{8}{9}$

$\frac{1}{2}$ seg. ACE $219\frac{4}{9}$
OE $5\frac{5}{6}$

$1097\frac{2}{9}$
183 nearly

$1280\frac{2}{9}$

20 half length
20

400
20

3) 8000

$2666\frac{2}{3}$
$1280\frac{2}{9}$

$1386\frac{4}{9}$

or 1386.44
4665.21 mult. inver.

138644
27739
6932
832
83
5

17423.5 Ansr.

Prob. 17. To find the Solidity of the Middle Frustum or Zone of a Circular Spindle.

From the square of half the length of the whole spindle, take $\frac{1}{3}$ of the square of half the length of the middle frustum, and multiply the remainder by the said half length of the frustum.——Multiply the central distance by the revolving area, which generates the middle frustum. Subtract this latter product from the former; and the remainder multiplied by 6.2832, or twice 3.1416, will give the contents.

Ex. Required the solidity of the frustum, whose length m n is 40 inches, also its greatest diameter EF is 32, and least diameter AD or BC 24.

Draw DG parallel to m n, then we
have DG $= \frac{1}{2}$m n $= 20$,

and $EG = \frac{1}{2}EF - \frac{1}{2}AD = 4,$
chord $DE^2 = DG^2 + GE^2 = 416,$
and $DE^2 \div EG = \frac{416}{4} = 104$ the diameter of the generating circle.
or the radius $OE = 52,$
hence $OI = 52 - 16 = 36$ the central distance,
and $HI^2 = OH^2 - OI^2 = 52^2 - 36^2 = 1408,$
$\frac{1}{3} DG^2 = \frac{1}{3}$ of $400 =$ .. .. $133\frac{1}{3},$

	$1274\frac{2}{3}$
DG	20
	$25493\frac{1}{3}$
	1st prod.

$GE \div 2\,OE = \frac{4}{104} = \frac{1}{26} = .03846$ a ver. sine

Its tab. segment ..	.00994
but 104^2 is ..	10816
area of seg. DECGD	107.51104
$mD \times mn = 12 \times 40$	480.
gener. area m DEC n	587.51104
OI	36
	21150.39744 2d product
	25493.33333 1st product
	4342.93589
	2382.6 mult inv.
	260576
	8686
	3474
	130
	9
	27287.5 Ansr.

Prob. 18. To find the Superficies or Solidity of any Regular Body.

1. Multiply the tabular area, (taken from the following table,) by the square of the linear edge of the body for the superficies.

2. Multiply the tabular solidity by the cube of the linear edge, for the solid contents.

Surfaces and Solidities of Regular Bodies.			
No. of Sides.	Names.	Surfaces.	Solidities.
4	Tetraedron	1.73205	0.11785
6	Hexaedron	6.00000	1.00000
8	Octaedron	3.46410	0.47140
12	Dodecaedron	20.64573	7.66312
20	Icosaedron	8.66025	2.18169

Ex. If the linear edge or side of a tetraedron be 3, required its surface and solidity.

The square of 3 is 9, and the cube 27. Then,

$$\begin{array}{lr@{\qquad}rl}
\text{tab. sur.} & 1.73205 & 0.11785 & \text{tab. sol.} \\
 & 9 & 27 & \\
\hline
\text{superf.} & 15.58845 & 82495 & \\
 & & 23570 & \\
\hline
 & \text{solidity} & 3.18195 &
\end{array}$$

Prob. 19. To find the Surface of a Cylindrical Ring.

This figure being only a cylinder bent round into a ring, its surface and solidity may be found as in the cylinder, namely, by multiplying the axis, or length of the cylinder, by the circumference of the ring or section, for the surface; and by the area of a section, for the solidity. Or use the following rules:

For the surface.——To the thickness of the ring add the inner diameter; multiply this sum by the thickness, and the product again by 9.8696, or the square of 3.1416.

Ex. Required the superficies of a ring, whose thickness AB is 2 inches, and inner diameter BC is 12 inches.

$$\begin{array}{r@{\qquad}r}
12 & 9.8696 \\
2 & 28 \\
\hline
14 & 789568 \\
2 & 197392 \\
\hline
28 & 276.3488 \text{ Ansr.}
\end{array}$$

Prob. 20. To find the Solidity of a Cylindrical Ring.

To the thickness of the ring add the inner diameter; then multiply the sum by the square of the thickness, and the product again by 2.4674, or $\frac{1}{4}$ of the square of 3.1416, for the solidity.

Ex. Required the solidity of the ring whose thickness is 2 inches, and its inner diameter 12.

$$\begin{array}{r@{\qquad}r}
12 & 2.4674 \\
2 & 56 \\
\hline
14 & 148044 \\
4 & 123370 \\
\hline
56 & 138.1744 \text{ Ansr.}
\end{array}$$

USEFUL RECEIPTS.

Compounds of Metals.

Fusible metal.—No. 1.

4 oz. of bismuth,
2½ oz. of lead, and
1½ oz. of tin.

Put the bismuth into a crucible, and, when it is melted, add the lead and tin. This will form an alloy fusible at the temperature of boiling water.

No. 2.——1 oz. of zinc,
1 oz. of bismuth, and
1 oz. of lead.

This alloy is so very fusible, that it will remain in a state of fusion if put on a sheet of paper and held over the flame of a candle or lamp.

No. 3.——3 parts of lead,
2 parts of tin, and
5 parts of bismuth,

will form an alloy fusible at 197° Fahrenheit, peculiarly applicable to casting, or the taking of impressions from gems, seals, &c. In making casts with this and similar alloys, it is necessary to use the metal at as low a temperature as possible; otherwise, the water adhering to the things from which the casts are to be taken, forms vapour, and produces bubbles. The fused metal should be poured into a tea-cup, and allowed to cool, till just ready to set at the edges, when it must be poured into the mould. In taking impressions from gems, seals, &c. the fused alloy should be placed on paper or pasteboard, and stirred about till it has, by cooling, attained the consistence of paste, at which moment the die, gem, or seal should be stamped on it, and a very sharp impression will then be obtained.

Bath metal is a mixture of

4½ oz. of zinc, with
1 lb. of brass.

Brass is composed of

4½ lb. of copper, and
1½ lb. of zinc.

But brass that is to be cast into plates, from which pans and kettles are to be made, and wire is to be drawn, must, instead of using the zinc in a pure state, be composed of

56 lb. of the finest calamine, or ore of zinc, and
34 lb. of copper.

Old brass, which has been frequently exposed to the action of fire, when mixed with the copper and calamine, renders the brass far more ductile and fitter for the making of fine wire, than it would be without it; but the German brass, particularly that of Nuremburgh, is, when drawn into wire, said to be far preferable to any made in England, for the strings of musical instruments.

Pinchbeck.—No. 1.

5 oz. of pure copper, and
1 oz. of zinc.

The zinc must not be added till the copper is in a state of fusion. Some use only half this quantity of zinc, in which proportion the alloy is more easily worked, especially in the making of jewellery.

No. 2.——1 oz. of brass,
2 oz. of copper,

Fused together, under a coat of charcoal dust.

Prince's metal. No. 1.

3 oz. of copper, and
1 oz. of zinc.
Or, 8 oz. of brass, and
1 oz. of zinc.

No. 2.——4 oz. of copper, and
2 oz. of zinc.

In this last the copper must be fused before the zinc is added. When they have combined, a very beautiful and useful alloy is formed, called Prince Rupert's Metal.

Bell metal.—No. 1.

6 parts of copper, and
2 parts of tin.

These proportions are the most approved, for bells, throughout Europe and in China. In the union of the two metals the combination is so complete, that the specific gravity of the alloy is greater than that of the two metals in an uncombined state.

No. 2.——10 parts of copper, and
2 parts of tin.

It may, in general, be observed, that a less proportion of tin is used for making church-bells than clock-bells; and that a little zinc is added for the bells of repeating watches, and other small bells.

Tutania, or britannia metal.—No. 1.

4 oz. of plate brass, and
4 oz. of tin; when in fusion, add
4 oz. of bismuth, and
4 oz. of regulus of antimony.

This is the composition, or hardening, that is to be added, at discretion, to melted tin, until it has acquired the requisite degree of colour and hardness.

No. 2.—Melt together, 2 lb. of plate brass,
2 lb. of tin,

2 lb. of bismuth,
2 lb. regulus of antimony,
2 lb. of a mixture of copper and arsenic, either by cementation or melting.

This composition is to be added, at discretion, to melted tin.

No. 3.——1 lb. of copper,
1 lb. of tin, and
2 lb. of regulus of antimony, with or without a little bismuth.

No. 4.——8 oz. of shruff brass,
2 lb. regulus of antimony, and
10 lb. of tin.

German tutania.

2 drachms of copper,
1 oz regulus of antimony, and
12 oz. of tin.

Spanish tutania.—No. 1.

8 oz. of scrap iron and steel,
1 lb. of antimony, and
3 oz. of nitre.

The iron or steel must be heated to a white heat, and the antimony and nitre must be added in small portions. Melt and harden 1 lb. of tin with 2 oz. of this compound.

No. 2.—Melt together, 4 oz. of antimony,
1 oz. of arsenic, and
2 lb. of tin.

The first of these Spanish alloys would be a beautiful metal if arsenic were added.

Engestroom tutania.

4 parts copper,
8 parts regulus of antimony, and
1 part bismuth,

When added to 100 parts of tin, this compound will be ready for use.

Queen's metal.—No. 1.

4½ lb. of tin,
½ lb. bismuth,
½ lb. antimony, and
½ lb. lead.

This alloy is used for the making of tea-pots and other vessels, which are required to imitate silver. It retains its lustre to the last.

No. 2.——100 lb. of tin,
8 lb. regulus of antimony,
1 lb. bismuth, and
4 lb. copper.

White metal.—No. 1.
10 oz of lead,
6 oz. of bismuth, and
4 drachms regulus of antimony.
No. 2.——2 lb. of regulus of antimony,
8 oz. of brass, and
10 oz. of tin.

Common hard white metal.
1 lb of brass,
1¼ oz. of zinc, and
½ oz. of tin.

Tombac. 16 lb. of copper,
1 lb of tin, and
1 lb. of zinc.

Red tombac. 5½ lb. of copper, and
½ lb. of zinc.

The copper must be fused in the crucible before the zinc is added. This alloy is of a reddish colour, and possesses more lustre, and is of greater durability, than copper.

White tombac. Copper and
Arsenic,
Put together in a crucible, and melted, covering the surface with muriate of soda, to prevent oxidation, will form a white brittle alloy.

Gun metal.—No. 1. 112 lb. of Bristol brass,
14 lb. zinc, and
7 lb. block tin.
No. 2.——9 parts copper, and
1 part tin.

The above compounds are those used in the manufacture of small and great brass guns, swivels, &c.

Blanched copper. 8 oz. of copper, and
½ oz. of neutral arsenical salt,
fused together, under a flux composed of calcined borax, charcoal dust and fine powder glass.

Specula of telescopes.
7 lb. of copper, and when fused, add
3 lbs. of zinc, and
4 lb. of tin.
These metals will combine and form a beautiful alloy of great lustre, and of a light yellow colour, fitted to be made into specula for telescopes. Mr Mudge used only copper and grain tin, in the proportion of two pounds to fourteen and a half ounces.

Kustitien's metal for tinning.
To 1 lb. of malleable iron, at a white heat, add

5 oz. of regulus of antimony, and
24 lb. of the purest Molucca tin.

This alloy polishes without the blue tint, and is free from lead or arsenic.

Metal for flute-key valves.
4 oz. lead, and
2 oz. antimony,

fused in a crucible, and cast into a bar, forms an alloy of considerable hardness and lustre. It is used by flute manufacturers, (when turned into small buttons in a lathe,) for making valves to stop the key-holes of flutes.

Printers' types. 10 lb. of lead, and
2 lb. of antimony.

The antimony must be thrown into the crucible when the lead is in a state of fusion. The antimony gives a hardness to the lead, without which the type would speedily be rendered useless, in a printing press. Different proportions of lead, copper, brass, and antimony, frequently constitute this metal. Every artist has his own proportions, so that the same composition cannot be obtained from different foundries; each boasts of the superiority of his own mixture.

Small types and stereotype plates.—No. 1.
9 lb. of lead, and when melted, add
2 lb. of antimony, and
1 lb. of bismuth.

This alloy expands as it cools, and is, therefore, well suited for the formation of small printing types, (particularly when many are cast together, to form stereotype plates,) as the whole of the mould is accurately filled with the alloy; consequently, there can be no blemish in the letters.

No. 2.——8 parts lead,
2 parts antimony, and
½ part tin.

For the manufacture of stereotype plates, plaster of Paris, of the consistence of a batter pudding before baking, is poured over the letter-press page, and worked into the interstices of the types with a brush. It is then collected from the sides, by a slip of iron or wood, so as to lie smooth and compact. In about two minutes the whole mass is hardened into a solid cake. This cake, which is to serve as the matrix of the stereotype plate, is now put upon a rack in an oven, where it undergoes great heat, so as to drive off superfluous moisture. When ready for use, these moulds, according to their size, are placed in flat cast-iron pots, and are covered over with another piece of cast iron, perforated at each end, to admit the metallic composition intended for the preparation of the stereotype plates. The flat cast-iron pots are now fastened in a crane, which carries them steadily to the metallic bath, or melting-pot, where they are immersed, and kept for a considerable time, until all the pores and crevices of the mould are completely and accurately filled. When this has taken place, the pots are elevated from the bath, by working the crane, and

are placed over a water trough, to cool gradually. When cold, the whole is turned out of the pots, and the plaster being separated, by hammering and washing, the plates are ready for use, having received the most exact and perfect impression.

Metallic casts from engravings on copper.

A most important discovery has lately been made, which promises to be of considerable utility in the fine arts: some very beautiful specimens of metallic plates, of a peculiar composition, have lately appeared, under the name of "cast engravings." This invention consists in taking moulds from every kind of engravings, with line, mezzotinto, or aquatinta, and pouring on this mould an alloy, in a state of fusion, capable of taking the finest impression. The obvious utility of this invention, as applicable to engravings which meet with a ready sale, and of which great numbers are required, will be incalculable; as it will wholly prevent the expense of retracing, which forms so prominent a charge in all works of an extended sale. No sooner is one cast worn out, than another may be immediately procured from the original plate, so that every impression will be a proof. Thus, the works of our most celebrated artists may be handed down, *ad infinitum*, for the improvement and delight of future ages, and will afford, at the same time, the greatest satisfaction to every lover of the fine arts.

Common pewter.	7 lb. of tin,
	1 lb. of lead,
	6 oz. of copper, and
	2 oz. of zinc.

The copper must be fused before the other ingredients are added. This combination of metals will form an alloy of great durability and tenacity; also, of considerable lustre.

Best pewter.	100 parts tin, and
	17 parts regulus of antimony.
Hard pewter.	12 lb. of tin,
	1 lb. regulus of antimony, and
	4 oz. of copper.
Common solder.	2 lb. of lead, and
	1 lb. of tin.

The lead must be melted before the tin is added. This alloy, when heated by a hot iron, and applied to the tinned iron with powdered rosin, acts as a cement or solder; it is also used to join lead pipes, &c. &c.

Soft solder.	2 lb. of tin, and
	1 lb. of lead.
Solder for steel joints.	
	19 dwts. of fine silver,
	1 dwt. copper, and
	2 dwts. brass,

melted together under a coat of charcool dust. This solder possesses several advantages over the usual zinc soda, or brass, when employed in soldering cast-steel, &c. as it fuses with less heat, and its whiteness has a better appearance than brass.

Silver solder for jewellers.
19 dwts. of fine silver,
1 dwt. copper, and
10 dwts. brass.

Silver solder for plating.
10 dwts. brass, and
1 oz. pure silver.

Gold solder. 12 dwts. pure gold,
2 dwts. pure silver, and
4 dwts. copper.

Brass solder for iron.—Thin plates of brass are to be melted between the pieces that are to be joined. If the work be very fine, as when two leaves of a broken saw are to be brazed together, cover it with pulverized borax, melted with water, that it may incorporate with the brass powder, which is added to it: the piece must be then exposed to the fire, without touching the coals, and heated till the brass is seen to run.

Bronze.——7 lbs. pure copper,
3 lbs. zinc, and
2 lbs. tin.

The copper must be fused before the other ingredients are added. These metals, when combined, form the bronze so much used, both in ancient and modern times, in the formatioh of busts, medals, and statues.

Composition of ancient statues.

According to Pliny, the metal used by the Romans for their statues, and for the plates on which they engraved inscriptions, was composed in the following manner. They first melted a quantity of copper, into which they put 1-3d of its weight of old copper, which had been long in use; to every 100 lbs. weight of this mixture, they added 12½ lbs. of an alloy composed of equal parts of lead and tin.

Mock platina.—Melt together
8 oz. of brass, and
5 oz. of zinc.

Useful alloy of gold with platinum.
7½ dr. pure gold, and
½ dr. platinum.

The platinum must be added when the gold is perfectly melted. The two metals will combine intimately, forming an alloy rather whiter than pure gold, but remarkably ductile and elastic; it is also less

perishable than pure gold, or jeweller's gold: but more readily fusible than that metal.

These excellent qualities must render this alloy an object of great interest to workers in metals. For springs where steel cannot be used, it will prove exceedingly advantageous.

It is a curious circumstance, that the alloy of gold and platinum is soluble in nitric acid, which does not act on either of the metals in a separate state. It is remarkable, too, that the alloy has very nearly the colour of platinum, even when composed of eleven parts of gold to one of the former metal.

Ring-gold. 6 dwts. 12 grs. Spanish copper,
3 dwts. 16 grs. fine silver, and
1 oz. 5 dwts. gold coin.

Gold from 35s. to 40s. per ounce.
8 dwts. 8 grs. Spanish copper,
10 dwts. fine silver, and
1 oz. gold coin.

Manheim-gold, or similor.
3½ oz. of copper,
1½ oz. of brass, and
15 gr. of pure tin.

Gilding-metal. 4 parts of copper,
1 part of Bristol old brass, and
14 oz of tin to every pound of copper.

For common jewellery. 3 parts of copper,
1 part of Bristol old brass, and
4 oz. of tin to every pound of copper.

If this alloy is for fine polishing, the tin may be omitted, and a mixture of lead and antimony substituted. Paler polishing metal is made by reducing the copper to two or to one part.

Yellow dipping metal.—No. 1.
2 parts of Cheadle brass,
1 part of copper, with a little
Bristol old brass, and
¼ oz. of tin to every pound of copper.

This alloy is almost of the colour of gold coin. Cheadle brass is the darkest, and gives the metal a greenish hue. Old Bristol brass is pale and yellow.

No. 2.—1 lb. of copper, and
5 oz. of zinc.

The copper should be tough cake, and not tile.

When antimony is used instead of tin, it should be in smaller quantity, or the metal will be brittle.

Imitation of silver. ¾ oz. of tin, and
1 lb. of copper,

Will make a pale bell-metal, which will roll and ring very near to sterling silver.

PREPARATION OF FOILS.

Foils are thin plates or leaves of metal that are put under stones, or compositions in imitation of stones, when they are set.

The intention of foils is either to increase the lustre or play of the stones, or more generally improve the colour, by giving an additional force to the tinge, whether it be natural or artificial, by that of a ground of the same hue, which the foil is in this case made to be.

There are consequently two kinds of foils; the one is colourless, where the effect of giving lustre or play to the stone is produced by the polish of the surface, which makes it act as a mirror, and by reflecting the light, prevents that deadness which attends the having a duller gound under the stone, and brings it, by the double refraction of the light that is caused, nearer to the effect of the diamond. The other is coloured with some pigment or stain of the same hue as the stone, or of some other which is intended to modify and change the hue of the stone in some degree; as, where a yellow foil may be put under green, which is too much inclining to the blue, or under crimson, where it is desired to have the appearance more orange or scarlet.

Foils may be made of copper or tin; and silver has been sometimes used, with which it has been advised, for some purposes, to mix gold; but the expense of either is needless, as copper may be made to answer the same end.

To prepare copper for foils.—Where coloured foils are wanted, copper may therefore be best used, and may be prepared for the purpose by the following means.

Take copper plates beaten to a proper thickness, and pass them betwixt a pair of fine steel rollers very close set, and draw them as thin as is possible to retain a proper tenacity. Polish them with very fine whiting, or rotten stone, till they shine, and have as much brightness as can be given them, and they will then be fit to receive the colour.

To whiten foils.—Where the yellow, or rather orange colour of the ground would be injurious to the effect, as in the case of purples, or crimson red, the foils should be whitened, which may be done by the following manner.

Take a small quantity of silver, and dissolve it in aqua-fortis, and then put bits of copper into the solution, and precipitate the silver; which being done, the fluid must be poured off, and fresh water added to it, to wash away all the remainder of the first fluid; after which the silver must be dried; an equal weight of cream of tartar and common salt must then be ground with it, till the whole is reduced to a very fine powder; and with this mixture the foils, being first slightly moistened, must be rubbed by the finger, or a bit of linen rag, till they be of the degree of whiteness desired; after which, if it appear to be wanted, the polish must be refreshed.

The tin-foils are only used in the case of colourless stones, where

quicksilver is employed; and they may be drawn out by the same rollers, but need not be further polished, as that effect is produced by other means in this case.

Foils for crystals, pebbles, or paste, to give the lustre and play of diamonds.—The manner of preparing foils, so as to give colourless stones the greatest degree of play and lustre, is by raising so high a polish or smoothness on the surface, as to give them the effect of a mirror, which can only be done, in a perfect manner, by the use of quicksilver, applied in the same general way as in the case of looking-glass. The method by which it may be best performed is as follows.

Take leaves of tin, prepared in the same manner as for silvering looking-glasses, and cut them into small pieces of such size as to cover the surface of the sockets of the stones that are to be set. Lay three of these then, one upon another, and having moistened the inside of the socket with thin gum-water, and suffered it to become again so dry, that only a slight stickiness remains, put the three pieces of leaves, lying on each other, into it, and adapt them to the surface in as even a manner as possible. When this is done, heat the socket, and fill it with warm quicksilver, which must be suffered to continue in it three or four minutes, and then gently poured out. The stone must then be thrust into the socket, and closed with it, care having been taken to give such room for it that it may enter without stripping off the tin and quicksilver from any part of the surface. The work should be well closed round the stone, to prevent the tin and quicksilver contained in the socket from being shaken out by any violence.

The lustre of stones set in this manner will continue longer than when they are set in the common way, as the cavity round them being filled, there will be no passage found for moisture, which is so injurious to the wear of stones treated in any other way.

This kind of foil likewise gives some lustre to glass or other transparent matter, which has little of itself; but to stones or pastes, that have some share of play, it gives a most beautiful brilliance.

To colour foils.—Two methods have been invented for colouring foils: the one by tinging the surface of the copper of the colour required by means of smoke, the other by staining or painting it with some pigment or other colouring substance.

The colours used for painting foils may be tempered with either oil, water rendered duly viscid by gum-arabic, size, or varnish. Where deep colours are wanted, oil is most proper, because some pigments become wholly transparent in it, as lake or Prussian blue; the yellow and green may be better laid on in varnish, as these colours may be had in perfection from a tinge wholly dissolved in spirit of wine, in the same manner as in the case of lacquers; and the most beautiful green is to be produced by distilled verdigris, which is apt to lose its colour and turn black with oil. In common cases, however, any of the colours may be, with the least trouble, laid on with isinglass size, in the same manner as the glazing colours used in miniature painting.

Ruby colours.—For red, where the ruby is to be imitated, a little lake used in isinglass size, carmine, or shell-lac varnish, is to be employed, if the glass or paste be of a full crimson, verging towards the purple; but if the glass incline to the scarlet, or orange, very bright lake (that is, not purple,) may be used alone in oil.

Garnet red.—For the garnet red, dragon's blood dissolved in seed-lac varnish may be used; and for the vinegar garnet, the orange-lake tempered with shell-lac varnish, will be found excellent.

Amethyst.—For the amethyst, lake, with a little Prussian blue, used with oil, and very thinly spread on the foil, will completely answer the end.

Blue.—For blue, where a deep colour, or the effect of the sapphire is wanted, Prussian blue, that is not too deep, should be used in oil, and it should be spread more or less thinly on the foil according to the lightness or deepness of the colour required.

Eagle marine.—For the eagle-marine, common verdigris, with a little Prussian blue, tempered in shell-lac varnish.

Yellow.—Where a full yellow is desired, the foil may be coloured with a yellow lacquer, laid on as for other purposes; and for the slighter colour of topazes, the burnish and foil itself will be sufficiently strong without any addition.

Green.—For green, where a deep hue is required, the crystals of verdigris, tempered in shell-lac varnish, should be used, but where the emerald is to be imitated, a little yellow lacquer should be added, to bring the colour to a truer green, and less verging to the blue.

Other colours.—The stones of more diluted colour, such as the amethyst, topaz, vinegar-garnet, and eagle-marine, may be very cheaply imitated, by transparent white glass or paste, even without foils. This is to be done by tempering the colours above enumerated with turpentine and mastic, and painting the socket in which the counterfeit stone is to be set with the mixture, the socket and stone itself being previously heated. In this case, however, the stone should be immediately set, and the socket closed upon it before the mixture cools and grows hard. The orange-lake above-mentioned was invented for this purpose, in which it has a beautiful effect, and was used with great success by a considerable manufacturer. The colour it produces is that of the vinegar-garnet, which it affords with great brightness. The colours before directed to be used in oil should be extremely well ground in oil of turpentine, and tempered with old nut or poppy-oil; or, if time can be given for their drying, with strong fat oil, diluted with spirit of turpentine, which will gain a fine polish of itself.

The colours used in varnish should be likewise thoroughly well ground and mixt; and in the case of the dragon's blood in the seed-lac varnish and the lacquer, the foils should be warmed before they are laid out. All the mixtures should be laid on the foils with a broad soft brush, which must be passed from one end to the other, and no part should be crossed, or twice gone over, or, at least, not till the

first coat can be dry; when, if the colour do not lie strong enough, a second coat may be given.

GILDING, SILVERING, AND TINNING.

Gold powder for gilding.—Gold powder may be prepared in 3 different ways:—1st, put into an earthen mortar some gold-leaf, with a little honey, or thick gum-water, and grind the mixture till the gold is reduced to extremely minute particles. When this is done, a little warm water will wash out the honey or gum, leaving the gold behind in a pulverulent state.

2nd.—Dissolve pure gold, (or the leaf,) in nitro-muriatic acid and then precipitate it by a piece of copper, or by a solution of sulphate of iron. The precipitate, (if by copper,) must be digested in distilled vinegar, and then washed, (by pouring water over it repeatedly,) and dried. This precipitate will be in the form of a very fine powder: it works better, and is more easily burnished than gold-leaf ground with honey, as above.

And 3d, or the best method of preparing gold powder, is by heating a prepared amalgam of gold, in an open clean crucible, and continuing the strong heat, until the whole of the mercury is evaporated; at the same time constantly stirring the amalgam with a glass rod. When the mercury has completely left the gold, the remaining powder is to be ground in a Wedgewood's mortar, with a little water, and afterwards dried. It is then fit for use.

Although the last mode of operating has been here given, the operator cannot be too much reminded of the danger attending the sublimation of mercury. In the small way here described, it is impossible to operate without danger; it is therefore better to prepare it according to the former directions, than to risk the health by the latter.

To cover bars of copper, &c. with gold, so as to be rolled out into sheets.—This method of *gilding* was invented by Mr Turner, of Birmingham. Mr Turner first prepares ingots or pieces of copper or brass, in convenient lengths and sizes. He then cleans them from impurity, and makes their surfaces level, and prepares plates of pure gold, or gold mixed with a portion of alloy, of the same size as the ingots of metal, and of suitable thickness. Having placed a piece of gold upon an ingot intended to be plated, he hammers and compresses them both together, so that they may have their surfaces as nearly equal to each other as possible, and then binds them together with wire, in order to keep them in the same position during the process required to attach them. Afterwards he takes silver filings, which he mixes with borax, to assist the fusion of the silver. This mixture he lays upon the edge of the plate of gold, and next to the ingot of metal. Having thus prepared the two bodies, he places them on a fire in a stove or furnace, where they remain until the silver

and borax placed along the edges of the metals melt, and until the adhesion of the gold with the metal is perfect. He then takes the ingot carefully out of the stove. By this process the ingot is plated with gold, and prepared ready for rolling into sheets.

To gild in colours.—The principal colours of gold for gilding are red, green, and yellow. These should be kept in different amalgams. The part which is to remain of the first colour is to be stopped off with a composition of chalk and glue; the variety required is produced by gilding the unstopped parts with the proper amalgam, according to the usual mode of gilding.

Sometimes the amalgam is applied to the surface to be gilt, without any quicking, by spreading it with aqua-fortis; but this depends on the same principle as a previous quicking.

Grecian gilding.—Equal parts of sal-ammoniac and corrosive sublimate are dissolved in spirit of nitre, and a solution of gold made with this menstruum. The silver is brushed over with it, which is turned black, but on exposure to a red heat it assumes the colour of gold.

To dissolve gold in aqua-regia.—Take an aqua-regia, composed of two parts of nitrous acid and one of marine acid; or of one part of sal-ammoniac and four parts of aqua-fortis; let the gold be granulated, put into a sufficient quantity of this menstruum, and exposed to a moderate degree of heat. During the solution, an effervescence takes place, and it acquires a beautiful yellow colour, which becomes more and more intense, till it has a golden or even orange colour. When the menstruum is saturated, it is very clear and transparent.

To gild iron or steel with a solution of gold.—Make a solution of 8 ounces of nitre and common salt with 5 ounces of crude alum in a sufficient quantity of water; dissolve half an ounce of gold thinly plated and cut, and afterwards evaporate to dryness. Digest the residuum in rectified spirit of wine or æther, which will perfectly abstract the gold. The iron is brushed over with this solution and becomes immediately gilt.

To gild by dissolving gold in aqua-regia.—Fine linen rags are soaked in a saturated solution of gold in aqua-regia, gently dried, and afterwards burnt to tinder. The substance to be gilt must be well polished; a piece of cork is first dipped into a solution of common salt in water, and afterwards into the tinder, which is well rubbed on the surface of the metal to be gilt, and the gold appears in all its metallic lustre.

Amalgam of gold in the large way.—A quantity of quicksilver is put into a crucible or iron ladle, which is lined with clay, and exposed to heat till it begins to smoke. The gold to be mixed should be previously granulated, and heated red hot, when it should be added to the quicksilver, and stirred about with an iron rod till it is perfectly dissolved. If there should be any superfluous mercury, it may be separated by passing it through clean soft leather; and the

remaining amalgam will have the consistence of butter, and contain about 3 parts of mercury to 1 of gold.

To gild by amalgamation.—The metal to be gilt is previously well cleaned on its surface, by boiling in a weak pickle, which is a very dilute nitrous acid. A quantity of aqua-fortis is poured into an earthen vessel, and quicksilver put therein; when a sufficient quantity of mercury is dissolved, the articles to be gilt are put into the solution, and stirred about with a brush till they become white. This is called quicking. But, as during quicking by this mode, a noxious vapour continually arises, which proves very injurious to the health of the workmen, they have adopted another method, by which they, in a great measure, avoid that danger. They now dissolve the quicksilver in a bottle containing aqua-fortis, and leave it in the open air during the solution, so that the noxious vapour escapes into the air. Then a little of this solution is poured into a basin, and with a brush dipped therein, they stroke over the surface of the metal to be gilt, which immediately becomes quicked. The amalgam is now applied by one of the following methods:

1st. By proportioning it to the quantity of articles to be gilt, and putting them into a white hat together, working them about with a soft brush, till the amalgam is uniformly spread.

Or, 2dly. By applying a portion of the amalgam upon one part, and spreading it on the surface, if flat, by working it about with a harder brush.

The work thus managed is put into a pan, and exposed to a gentle degree of heat; when it becomes hot, it is frequently put into a hat, and worked about with a painter's large brush, to prevent an irregular dissipation of the mercury, till at last the quicksilver is entirely dissipated by a repetition of the heat, and the gold is attached to the surface of the metal. This gilt surface is well cleaned by a wire brush, and then artists heighten the colour of the gold by the application of various compositions; this part of the process is called COLOURING.

To gild glass and porcelain.—No. 1.—Drinking and other glasses are sometimes gilt on their edges. This is done either by an adhesive varnish or by heat. The varnish is prepared by dissolving in boiled linseed oil an equal weight either of copal or amber. This is to be diluted by a proper quantity of oil of turpentine, so as to be applied as thin as possible to the parts of the glass intended to be gilt. When this is done, which will be in about twenty-four hours, the glass is to be placed in a stove, till it is so warm as almost to burn the fingers when handled. At this temperature the varnish will become adhesive, and a piece of leaf gold, applied in the usual way, will immediately stick. Sweep off the superfluous portions of the leaf, and when quite cold it may be burnished, taking care to interpose a piece of very thin paper, (India paper,) between the gold and the burnisher. If the varnish is very good, this is the best method of gilding glass, as the gold is thus fixed on more evenly than in any other way.

No. 2.—It often happens, when the varnish is but indifferent, that by repeated washings the gold wears off; on this account the practice of burning it in is sometimes had recourse to.

For this purpose, some gold powder is ground with borax, and in this state applied to the clean surface of the glass, by a camel's hair pencil; when quite dry, the glass is put into a stove heated to about the temperature of an annealing oven; the gum burns off, and the borax, by vitrifying, cements the gold with great firmness to the glass; after which it may be burnished. The gilding upon porcelain is in like manner fixed by heat and the use of borax; and this kind of ware being neither transparent nor liable to soften, and thus to be injured in its form in a low red heat, is free from the risk and injury which the finer and more fusible kinds of glass are apt to sustain from such treatment. Porcelain and other wares may be platinised, silvered, tinned, and bronzed, in a similar manner.

To gild leather.—In order to impress gilt figures, letters, and other marks upon leather, as on the covers of books, edgings for doors, &c. the leather must first be dusted over with very finely powdered yellow resin, or mastich gum. The iron tools or stamps are now arranged on a rack before a clear fire, so as to be well heated, without becoming red hot. If the tools are *letters*, they have an alphabetical arrangement on the rack. Each letter or stamp must be tried as to its heat, by imprinting its mark on the raw side of a piece of waste leather. A little practice will enable the workman to judge of the heat. The tool is now to be pressed downwards on the gold leaf, which will of course be indented, and show the figure imprinted on it. The next letter or stamp is now to be taken and stamped in like manner, and so on with the others, taking care to keep the letters in an even line with each other, like those in a book. By this operation the resin is melted; consequently the gold adheres to the leather: the superfluous gold may then be rubbed off by a cloth, the gilded impressions remaining on the leather. In this, as in every other operation, adroitness is acquired by practice.

The cloth alluded to should be slightly greasy, to retain the gold wiped off (otherwise there will be a great waste in a few months); the cloth will thus be soon completely saturated or loaded with the gold. When this is the case, these cloths are generally sold to the refiners, who burn them and recover the gold. Some of these afford so much gold by burning, as to be worth from a guinea to a guinea and a half.

To gild writings, drawings, &c. on paper or parchment.—Letters written on vellum or paper are gilded in three ways: in the first, a little size is mixed with the ink, and the letters are written as usual; when they are dry, a slight degree of stickiness is produced by breathing on them, upon which the gold leaf is immediately applied, and by a little pressure may be made to adhere with sufficient firmness. In the second method, some white-lead or chalk is ground up with strong size, and the letters are made with this by means of a brush: when the mixture is almost dry, the gold leaf may be laid on, and afterwards burnished. The last method is to mix up some

gold powder with size, and to form the letters of this by means of a brush. It is supposed that this latter method was that used by the monks in illuminating their missals, psalters, and rubrics.

To gild the edges of paper.—The edges of the leaves of books and letter paper are gilded whilst in a horizontal position in the book-binder's press, by first applying a composition formed of four parts of Armenian bole, and one of candied sugar, ground together with water to a proper consistence, and laid on by a brush with the white of an egg. This coating, when nearly dry, is smoothed by the burnisher, which is generally a crooked piece of agate, very smooth, and fixed in a handle. It is then slightly moistened by a sponge dipped in clean water, and squeezed in the hand. The gold leaf is now taken up on a piece of cotton from the leathern cushion, and applied on the moistened surface. When dry, it is to be burnished by rubbing the agate over it repeatedly from end to end, taking care not to wound the surface by the point of the burnisher. A piece of silk or India paper is usually interposed between the gold and the burnisher.

Cotton wool is generally used by book-binders to take the leaf up from the cushion, being the best adapted for the purpose on account of its pliability, smoothness, softness, and slight moistness.

To gild silk, satin, ivory, &c. by hydrogen gas. No. 1.—Immerse a piece of white satin, silk, or ivory in a solution of nitro-muriate of gold, in the proportion of one part of the nitro-muriate to three of distilled water. Whilst the substance to be gilded is still wet, immerse it in a jar of hydrogen gas: it will soon be covered by a complete coat of gold.

No. 2.—The foregoing experiment may be very prettily and advantageously varied as follows:—Paint flowers or other ornaments with a very fine camel's hair pencil, dipped in the above-mentioned solution of gold, on pieces of silk, satin, &c. &c. &c. and hold them over a Florence flask, from which hydrogen gas is evolved during the decomposition of the water by sulphuric acid and iron filings. The painted flowers, &c. in a few minutes will shine with all the splendour of the purest gold. A coating of this kind will not tarnish on exposure to the air, or in washing.

Oil gilding on wood.—The wood must first be covered, or primed, by two or three coatings of boiled linseed oil and carbonate of lead, in order to fill up the pores, and conceal the irregularities of the surface, occasioned by the veins in the wood. When the priming is quite dry, a thin coat of gold-size must be laid on. This is prepared by grinding together some red oxide of lead with the thickest drying oil that can be procured, and the older the better, that it may work freely: it is to be mixed, previously to being used, with a little oil of turpentine, till it is brought to a proper consistence. If the gold-size is good, it will be sufficiently dry in twelve hours, more or less, to allow the artist to proceed to the last part of the process, which is the application of the gold. For this purpose a leaf of gold is spread on a cushion, (formed by a few folds of flannel secured on a piece of wood, about eight inches square, by a tight covering of leather,) and

is cut into strips of a proper size by a blunt pallet knife; each strip being then taken upon the point of a fine brush, is applied to the part intended to be gilded, and is then gently pressed down by a ball of soft cotton; the gold immediately adheres to the sticky surface of the size, and after a few minutes, the dexterous application of a large camel's hair brush sweeps away the loose particles of the gold leaf without disturbing the rest. In a day or two the size will be completely dried, and the operation will be finished.

The advantages of this method of gilding are, that it is very simple, very durable, and not readily injured by changes of weather, even when exposed to the open air; and when soiled it may be cleaned by a little warm water and a soft brush; its chief employment is in outdoor work. Its disadvantage is, that it cannot be burnished, and therefore wants the high lustre produced by the following method.

To gild by burnishing.—This operation is chiefly performed on picture frames, mouldings, beadings, and fine stucco work. The surface to be gilt must be carefully covered with a strong size, made by boiling down pieces of white leather, or clippings of parchment, till they are reduced to a stiff jelly; this coating being dried, eight or ten more must be applied, consisting of the same size, mixed with fine Paris plaster or washed chalk; when a sufficient number of layers have been put on, varying according to the nature of the work, and the whole is become quite dry, a moderately thick layer must be applied, composed of size and Armenian bole, or yellow oxide of lead: while this last is yet moist, the gold leaf is to be put on in the usual manner; it will immediately adhere on being pressed by the cotton ball, and before the size is become perfectly dry, those parts which are intended to be the most brilliant are to be carefully burnished by an agate or dog's tooth fixed in a handle.

In order to save the labour of burnishing, it is a common, but bad practice, slightly to burnish the brilliant parts, and to deaden the rest by drawing a brush over them dipped in size; the required contrast between the polished and the unpolished gold is indeed thus obtained; but the general effect is much inferior to that produced in the regular way, and the smallest drop of water falling on the sized part occasions a stain. This kind of gilding can only be applied on in-door work; as rain, and even a considerable degree of dampness, will occasion the gold to peel off. When dirty, it may be cleaned by a soft brush, with hot spirit of wine, or oil of turpentine.

To gild copper, &c. by amalgam.—Immerse a very clean bright piece of copper in a diluted solution of nitrate of mercury. By the affinity of copper for nitric acid, the mercury will be precipitated: now spread the amalgam of gold rather thinly over the coat of mercury just given to the copper. This coat unites with the amalgam, but of course will remain on the copper. Now place the piece or pieces so operated on, in a clean oven or furnace, where there is no smoke. If the heat is a little greater than 600°, the mercury of the amalgam will be volatilized, and the copper will be beautifully gilt.

In the large way of gilding, the furnaces are so contrived that the

volatilized mercury is again condensed, and preserved for further use, so that there is no loss in the operation. There is also a contrivance by which the volatile particles of mercury are prevented from injuring the gilders.

To gild steel.—Pour some of the ethereal solution of gold into a wine glass, and dip therein the blade of a new pen-knife, lancet, or razor; withdraw the instrument, and allow the ether to evaporate. The blade will be found to be covered by a very beautiful coat of gold. A clean rag, or small piece of very dry sponge, may be dipped in the ether, and used to moisten the blade, with the same result.

In this case there is no occasion to pour the liquid into a glass, which must undoubtedly lose by evaporation; but the rag or sponge may be moistened by it, by applying either to the mouth of the phial. This coating of gold will remain on the steel for a great length of time, and will preserve it from rusting.

This is the way in which swords and other cutlery are ornamented. Lancets too are in this way gilded with great advantage, to secure them from rust.

To heighten the colour of yellow gold.

6 oz. saltpetre,
2 oz. copperas,
1 oz. white vitriol, and
1 oz. alum.

If it be wanted redder, a small portion of blue vitriol must be added. These are to be well mixed, and dissolved in water as the colour is wanted.

To heighten the colour of green gold.

1 oz. 10 dwts. saltpetre,
1 oz. 4 dwts. sal ammoniac,
1 oz. 4 dwts. Roman vitriol, and
18 dwts. verdigris,

Mix them well together, and dissolve a portion in water, as occasion requires.

The work must be dipped in these compositions, applied to a proper heat to burn them off, and then quenched in water or vinegar.

To heighten the colour of red gold.

To 4 oz. melted yellow wax, add
1½ oz. red ochre in fine powder,
1½ oz. verdigris calcined till it yield no fumes, and
½ oz. calcined borax.

It is necessary to calcine the verdigris, or else, by the heat applied in burning the wax, the vinegar becomes so concentrated as to corrode the surfaces, and make it appear speckled.

To separate gold from gilt-copper and silver.—Apply a solution of borax, in water, to the gilt surface, with a fine brush, and sprinkle over it some fine powdered sulphur. Make the piece red hot, and quench it in water. The gold may be easily wiped off with a scratch-brush, and recovered by testing it with lead.

Gold is taken from the surface of silver by spreading over it a

paste, made of powdered sal-ammoniac, with aqua-fortis, and heating it till the matter smokes, and is nearly dry; when the gold may be separated by rubbing it with a scratch-brush.

To silver by heat. No. 1.—Dissolve an ounce of pure silver in aqua-fortis, and precipitate it with common salt; to which add ½ lb. of sal-ammoniac, sandiver, and white vitriol, and ¼ oz. of sublimate.

No. 2.—Dissolve an ounce of pure silver in aqua-fortis; precipitate it with common salt, and add, after washing, 6 ounces of common salt, 3 ounces each of sandiver and white vitriol, and ¼ ounce of sublimate.

These are to be ground into a paste upon a fine stone with a muller; the substance to be silvered must be rubbed over with a sufficient quantity of the paste, and exposed to a proper degree of heat. Where the silver runs, it is taken from the fire, and dipped into weak spirit of salt to clean it.

Silvering on gilt work, by amalgamation.—Silver will not attach itself to any metal by amalgamation, unless it be first gilt. The process is the same as gilding in colours, only no acid should be used.

To silver in the cold way.

No. 1.—2 dr. tartar,
2 dr. common salt,
½ dr. of alum, and
20 grs. of silver, precipitated from the nitrous acid by copper.

Make them into a paste with a little water. This is to be rubbed on the surface to be silvered with a cork, &c.

No. 2.—Dissolve pure silver in aqua-fortis, and precipitate the silver with common salt; make this precipitate into a paste, by adding a little more salt and cream of tartar. It is applied as in the former method.

To silver copper ingots.—The principal difficulties in plating copper ingots are, to bring the surfaces of the copper and silver into fusion at the same time, and to prevent the copper from scaling; for which purposes fluxes are used. The surface of the copper on which the silver is to be fixed must be made flat by filing, and should be left rough. The silver is first annealed and afterwards pickled in weak spirit of salt; it is planished, and then scraped on the surface to be fitted on the copper. These prepared surfaces are annointed with a solution of borax, or strewed with fine powdered borax itself, and then confined in contact with each other, by binding wire. When they are exposed to a sufficient degree of heat, the flux causes the surfaces to fuse at the same time, and after they become cold, they are found firmly united.

Copper may likewise be plated by heating it, and burnishing leaf-silver upon it; so may iron and brass. This process is called French Plating.

To separate the silver from plated copper.—This process is applied to recover the silver from the plated metal, which has been rolled down for buttons, toys, &c. without destroying any large portion of

the copper. For this purpose, a menstruum is composed of 3 pounds of oil of vitriol, 1½ ounce of nitre, and a pound of water. The plated metal is boiled in it, till the silver is dissolved, and then the silver is recovered by throwing common salt into the solution.

To plate iron.—Iron may be plated by three different modes.

1st. By polishing the surface very clean and level with a burnisher; and afterwards by exposing it to a blueing heat, a leaf of silver is properly placed and carefully burnished down. This is repeated till a sufficient number of leaves is applied, to give the silver a proper body.

2d. By the use of a solder; slips of thin solder are placed between the iron and silver, with a little flux, and secured together by binding wire. It is then placed in a clear fire, and continued in it till the solder melts; when it is taken out, and on cooling is found to adhere firmly.

And 3d. By tinning the iron first, and uniting the silver by the intermediate of slips of rolled tin, brought into fusion in a gentle heat.

To tin copper and brass.—Boil six pounds of cream of tartar, four gallons of water, and eight pounds of grain tin, or tin shavings. After the materials have boiled a sufficient time, the substance to be tinned is put therein, and the boiling continued, when the tin is precipitated in its metallic form.

To tin iron and copper vessels.—Iron which is to be tinned, must be previously steeped in acid materials, such as sour whey, distillers' wash, &c.; then scoured and dipped in melted tin, having been first rubbed over with a solution of sal-ammoniac. The surface of the tin is prevented from calcining, by covering it with a coat of fat. Copper vessels must be well cleansed; and then a sufficient quantity of tin with sal-ammoniac is put therein, and brought into fusion, and the copper vessel moved about. A little resin is sometimes added. The sal-ammoniac prevents the copper from scaling, and causes the tin to be fixed wherever it touches. Lately, zinc has been proposed for lining vessels instead of tin, to avoid the ill consequences which have been unjustly apprehended.

To prepare the silver tree.—Pour into a glass globe or decanter, 4 drachms of nitrate of silver, dissolved in a pound or more of distilled water, and lay the vessel on the chimney piece, or in some place where it may not be disturbed. Now pour in 4 drachms of mercury. In a short time the silver will be precipitated in the most beautiful arborescent form, resembling real vegetation. This has been generally termed the Arbor Dianæ.

To prepare the tin tree.—Into the same or a similar vessel to that used in the last experiment, pour distilled water as before, and put in 3 drachms of muriate of tin, adding 10 drops of nitric acid, and shake the vessel until the salt be completely dissolved. Replace the zinc, (which must be cleared from the effects of the former experiment, as before, and set the whole aside to precipitate without disturbance. In a few hours the effect will be similar to the last, only that the tree of tin will have more lustre. In these experiments, it is surprising

to observe the laminæ shoot out as it were from nothing; but this phenomenon seems to proceed from a galvanic action of the metals and the water.

To prepare the lead tree.—Put ½ an ounce of the super-acetate of lead in powder, into a clear glass globe or wine decanter, filled to the bottom of the neck with distilled water, and 10 drops of nitric acid, and shake the mixture well. Prepare a rod of zinc with a hammer and file, so that it may be a quarter of an inch thick and 1 inch long; at the same time form notches in each side for a thread, by which it is to be suspended, and tie the thread so that the knot shall be uppermost, when the metal hangs quite perpendicular. When it is tied, pass the two ends of the thread through a perforation in the cork, and let them be again tied over a small splinter of wood which may pass between them and the cork. When the string is tied, let the length between the cork and the zinc be such, that the precipitant (the zinc) may be at equal distances from the side, bottom, and top of the vessel, when immersed in it. When all things are thus prepared, place the vessel in a place where it may not be disturbed, and introduce the zinc, at the same time fitting in the cork. The metal will very soon be covered with the lead, which it precipitates from the solution, and this will continue to take place until the whole be precipitated upon the zinc, which will assume the form of a tree or bush, whose leaves and branches are laminal, or plates of a metallic lustre.

Metallic watering, or for blanc moiré.—This article of Parisian invention, which is much employed to cover ornamental cabinet work, dressing-boxes, telescopes, opera glasses, &c. &c. is prepared in the following manner.

Sulphuric acid is to be diluted with from seven to nine parts of water; then dip a sponge or rag into it, and wash with it the surface of a sheet of tin. This will speedily exhibit an appearance of crystallization, which is the moiré.

This effect, however, cannot be easily produced upon every sort of sheet tin, for if the sheet has been much hardened by hammering or rolling, then the moiré cannot be effected until the sheet has been heated so as to produce an incipient fusion on the surface, after which the acid will act upon it, and produce the moiré. Almost any acid will do as well as the sulphuric, and it is said, that the citric acid, dissolved in a sufficient quantity of water, answers better than any other.

The moiré may be much improved by employing the blow-pipe, to form small and beautiful specks on the surface of the tin, previous to the application of the acid.

When the moiré has been formed, the plate is to be varnished and polished, the varnish being tinted with any glazing colour, and thus the red, green, yellow, and pearl coloured moirés are manufactured.

Chinese sheet lead.—The operation is carried on by two men; one is seated on the floor with a large flat stone before him, and with a movable flat stone-stand at his side. His fellow workman stands beside him with a crucible filled with melted lead; and having poured

a certain quantity upon the stone, the other lifts the movable stone, and dashing it on the fluid lead, presses it out into a flat and thin plate, which he instantly removes from the stone. A second quantity of lead is poured in a similar manner, and a similar plate formed, the process being carried on with singular rapidity. The rough edges of the plates are then cut off, and they are soldered together for use.

Mr. Waddell has applied this method, with great success, to the formation of thin plates of zinc, for galvanic purposes.

To plate looking glasses.—This art is erroneously termed silvering, for, as will be presently seen, there is not a particle of silver present in the whole composition.

On tin-foil, fitly deposited on a flat table, mercury is to be poured, and gently rubbed with a hare's foot; it soon unites itself with the tin, which then becomes very splendid, or, as the workmen say, is *quickened*. A plate of glass is then cautiously to be slid upon the tin-leaf, in such a manner as to sweep off the redundant mercury, which is not incorporated with the tin; lead weights are then to be placed on the glass, and, in a little time, the quicksilvered tin-foil adheres so firmly to the glass, that the weights may be removed without any danger of its falling off. The glass thus coated is a common looking-glass. About two ounces of mercury are sufficient for covering three square feet of glass.

The success of this operation depends much on the cleanness of the glass; and the least dirt or dust on its surface will prevent the adhesion of the amalgam or alloy.

Liquid foil for silvering glass globes.—No. 1.

1 oz. clean lead,
1 oz. fine tin,
1 oz. bismuth, and
10 oz. quicksilver.

The lead and tin must be put into the ladle first, and so soon as melted the bismuth must be added. Skim off the dross, remove the ladle from the fire, and before it sets, add the quicksilver: stir the whole carefully together, taking care not to breath over it, as the fumes of the mercury are very pernicious. Pour this through an earthen pipe, into the glass globe, which turn repeatedly round.

No. 2.——2 parts mercury,
1 part tin,
1 part lead, and
1 part bismuth.

No. 3.——4 oz. quicksilver, and
tin-foil.

The quantity of tin-foil to be added, is so much as will become barely fluid when mixed. Let the globe be clean and warm, and inject the quicksilver by means of a pipe at the aperture, turning it about till it is silvered all over. Let the remainder run out, and hang the globe up.

LACQUERING.

Lacquer for brass. 6 oz. seed lac,
2 oz. amber or copal, ground on porphyry,
40 gr. of dragon's blood,
30 gr. extract of red sandal wood, obtained by water,
36 gr. of oriental saffron,
4 oz. of pounded glass, and
40 oz. very pure alcohol.

To apply this varnish to articles or ornaments of brass, expose them to a gentle heat, and dip them into varnish. Two or three coatings may be applied in this manner, if necessary. The varnish is durable, and has a beautiful colour. Articles varnished in this manner may be cleaned with water and a bit of dry rag.

Lacquer for philosophical instruments.—This lacquer or varnish is destined to change, or to modify the colour of those bodies to which it is applied.

¾ oz. of gum guttæ,
2 oz. of gum sandarac,
2 oz. of gum elemi,
1 oz. of dragon's blood, of the best quality,
1 oz. of seed lac,
¾ oz. of terra merita,
2 grains of oriental saffron,
3 oz. of pounded glass, and
20 oz. of pure alcohol.

The tincture of saffron and of terra merita, is first obtained by infusing them in alcohol for twenty-four hours, or exposing them to the heat of the sun in summer. The tincture must be strained through a piece of clean linen cloth, and ought to be strongly squeezed. This tincture is poured over the dragon's blood, the gum elemi, the seed lac, and the gum guttæ, all pounded and mixed with the glass. The varnish is then made according to the directions before given.

It may be applied with great advantage to philosophical instruments: the use of it might be extended, also, to various cast or moulded articles with which furniture is ornamented.

If the dragon's blood be of the first quality, it may give too high a colour; in this case the dose may be lessened at pleasure, as well as hatt of the other colouring matters.

It is with a similar kind of varnish that the artists of Geneva give a golden orange colour to the small nails employed to ornament watch-cases; but they keep the process very secret. A beautiful bright colour might be easily communicated to this mixture; but they prefer the orange colour, produced by certain compositions, the preparation of which has no relation to that of varnish, and which has been successfully imitated with saline mixtures, in which orpiment is

a principal ingredient. The nails are heated before they are immersed in the varnish, and they are then spread out on sheets of dry paper.

Gold-coloured lacquer, for brass watch-cases, watch-keys, &c.

6 oz. of seed lac,
2 oz. of amber,
2 oz. of gum guttæ,
24 gr. of extract of red sandal wood in water,
60 gr. of dragon's blood,
36 gr. of Oriental saffron,
4 oz. of pounded glass, and
36 oz. of pure alcohol.

Grind the amber, the seed lac, gum guttæ, and dragon's blood on a piece of porphyry; then mix them with the pounded glass, and add the alcohol, after forming with it an infusion of the saffron and an extract of the sandal wood. The varnish must then be completed as before. The metal articles destined to be covered by this varnish, are heated, and those which will admit of it, are immersed in packets. The tint of the varnish may be varied, by modifying the doses of the colouring substances.

Lacquer of a less drying quality.

4 oz. seed lac,
4 oz. sandarac, or mastic,
½ oz. dragon's blood,
36 gr. terra merita,
36 gr. gum guttæ,
5 oz. pounded glass,
2 oz. clear turpentine,
32 oz. essence of turpentine

Extract, by infusion, the tincture of the colouring substances, and then add the resinous bodies according to the directions for compound mastic varnish.

Lacquer or varnishes of this kind are called changing, because, when applied to metals, such as copper, brass, or hammered tin, or to wooden boxes and other furniture, they communicate to them a more agreeable colour. Besides, by their contact with the common metals, they acquire a lustre which approaches that of the precious metals, and to which, in consequence of peculiar intrinsic qualities or certain laws of convention, a much greater value is attached. It is by means of these changing varnishes, that artists are able to communicate to their leaves of silver and copper, those shining colours observed in foils. This product of industry becomes a source of prosperity to the manufacturers of buttons and works formed with foil, which, in the hands of the jeweller, contributes with so much success to produce that reflection of the rays of light, which doubles the lustre and sparkling quality of precious stones.

It is to varnish of this kind that we are indebted for the manufacture of gilt leather, which, taking refuge in England, has given place to that of papier maché, which is employed for the decoration of palaces, theatres, &c.

In the last place, it is by the effect of a foreign tint obtained from the colouring part of saffron, that the scales of silver disseminated in *confection d' hyacinthe* reflect a beautiful gold colour.

The colours transmitted by different colouring substances require tones suited to the objects for which they are destined. The artist has it in his own power to vary them at pleasure. The addition of annatto to the mixture of dragon's blood, saffron, &c. or some changes in the doses of the mode intended to be made in colours. It is, therefore, impossible to give limited formulæ.

To make lacquer of various tints.

Infuse separately

4 oz. gum guttæ in
32 oz. of essence of turpentine,
1 oz. annatto, and
4 oz. dragon's blood, also in separate doses of essence.

These infusions may be easily made in the sun. After fifteen days' exposure, pour a certain quantity of these liquors into a flask, and by varying the doses different shades of colour will be obtained.

These infusions may be employed also for changing alcoholic varnishes; but in this case, the use of saffron, as well as that of red sandal wood, which does not succeed with essence, will soon give the tone necessary for imitating, with other tinctures, the colour of gold.

To bronze plaster figures.—For the ground, after it has been sized and rubbed down, take Prussian blue, verditer, and spruce ochre. Grind them separately in water, turpentine, or oil, according to the work, and mix them in such proportions as will produce the colour desired. Then grind Dutch metal in a part of this composition: laying it with judgment on the prominent parts of the figure, which produces a grand effect.

To brown gun barrels.—After the barrel is finished rub it over with aqúa-fortis, or spirit of salt, diluted with water. Then lay it by for a week, till a complete coat of oil is formed. A little oil is then to be applied, and after rubbing the surface dry, polish it with a hard-brush and a little bees' wax.

VARNISHES.

To make white copal varnish.—No. 1.—White oxide of lead, ceruse, Spanish white, white clay. Such of these substances as are preferred ought to be carefully dried. Ceruse and clays obstinately retain a great deal of humidity, which would oppose their adhesion to drying oil or varnish. The cement then crumbles under the fingers, and does not assume a body.

No. 2.—On 16 ounces of melted copal, pour 4, 6, or 8 ounces of linseed-oil, boiled and quite free from grease. When well mixed by repeated stirrings, and after they are pretty cool, pour in 16 ounces

of the essence of Venice turpentine. Pass the varnish through a cloth. Amber varnish is made the same way.

Black.—Lamp-black, made of burnt vine-twigs, and black of peach-stones. The lamp-black must be carefully washed, and afterwards dried. Washing carries off a great many of its impurities.

Yellow.—Yellow oxide of lead of Naples and Montpellier, both reduced to impalpable powder. These yellows are hurt by the contact of iron and steel; in mixing them up, therefore, a horn spatula with a glass mortar and pestle must be employed.

Gum guttæ, yellow ochre, or Dutch pink, according to the nature and tone of the colour to be imitated.

Blue.—Indigo, prussiate of iron, (Prussian blue), blue verditer, and ultra-marine. All these substances must be very much divided.

Green.—Verdigris, crystallized verdigris, compound green, (a mixture of yellow and blue.) The first two require a mixture of white in proper proportions, from a fourth to two-thirds, according to the tint intended to be given. The white used for this purpose is ceruse, or the white oxide of lead, or Spanish white, which is less solid, or white of Moudon.

Red.—Red sulphurated oxide of mercury, (cinnabar vermilion.) Red oxide of lead, (minium,) different red ochres, or Prussian reds, &c.

Purple.—Cochineal, carmine, and carminated lakes, with ceruse and boiled oil.

Brick red.—Dragon's blood.

Chamois colour.—Dragon's blood with a paste composed of flowers of zinc, or, what is still better, a little red vermilion.

Violet.—Red sulphurated oxide of mercury, mixed with lamp-black, washed very dry, or with the black of burnt vine-twigs; and to render it mellower, a proper mixture of red, blue, and white.

Pearl grey.—White and black; white and blue; for example, ceruse and lamp-black; ceruse and indigo.

Flaxen grey.—Ceruse, which forms the ground of the paste, mixed with a small quantity of Cologne earth, as much English red, or carminated lake, which is not so durable, and a particle of prussiate of iron, (Prussian-blue.)

To make varnishes for violins, &c.—To a gallon of rectified spirit of wine, add six ounces of gum sandarac, three ounces of gum mastich, and half a pint of turpentine varnish. Put the whole into a tin can, which keep in a warm place, frequently shaking it, for twelve days, until it is dissolved. Then strain, and keep it for use.

To dissolve elastic gum, &c.—M. Gossart, by an ingenious method, succeeded in forming India rubber into elastic tubes. Cut a bottle of the gum circularly, in a spiral slip, of a few lines in breadth; then plunge the whole of the slip into vitriolic ether, till it becomes softened; half an hour is generally sufficient for this purpose. The slip is then taken out of the liquid, and one of the extremities applied to the end of a mould, first rolling it on itself, and pressing it, then mounting spirally along the cylinder, taking care to lay over and

compress with the hand every edge, one against the other, so that there may not be any vacant space, and that all the edges may join exactly; the whole is then to be bound hard with a tape of an inch in width, taking care to turn it the same way with the slip of caoutchouc. Over the tape packthread is to be applied, in such a manner that, by every turn of the thread joining another, an equal pressure is given to every part. It is then left to dry, and the tube is made. In removing the bandage, great care must be taken that none of the outward surface, which may have lodged within the interstices of the tape, (of which the caoutchouc takes the exact impression,) may be pulled asunder. If it be found difficult to withdraw the mould, it may be plunged into hot water. If the mould were previously smoked or rubbed with chalk, it might be removed with less difficulty. Polished metallic cylinders are the most eligible moulds for this purpose. As solvents, oils of turpentine and lavender may be employed, but both are much slower of evaporating than ether, and the oil of turpentine, particularly, appears always to have a kind of stickiness. Nevertheless, there is a solvent which has not that inconvenience, is cheaper, and may easily be procured by every one, viz. *water*. Proceed in the same manner as with ether. The caoutchouc is sufficiently prepared for use when it has been a quarter of an hour in boiling water: by this time its edges are sometimes transparent. It is to be turned spirally round the mould, and replunged frequently into the boiling water, during the time employed in forming the tube. When the whole is bound with packthread, it is to be kept some hours in boiling water, after which it is to be dried, still keeping on the binding. This method may be successfully employed in forming the larger sort of tubes, and in any other instruments, but it would be impracticable to make the small tubes in this way.

Oil of lavender, of turpentine, and of spikenard, dissolve elastic gum, with the assistance of a gentle heat; but a mixture of volatile oil and alcohol forms a better solvent for it than oil alone, and the varnish dries sooner. If boiled in a solution of alum in water, it is rendered softer than in water alone. Yellow wax, in a state of ebullition, may be saturated with it, by putting it, cut in small pieces, gradually into it. By this means a pliable varnish is formed, which may be applied to cloth with a brush, but it still retains a clamminess.

To make caoutchouc varnish.

16 oz. of caoutchouc, or elastic resin,
16 oz. boiled linseed-oil, and
16 oz. of essence of turpentine.

Cut the caoutchouc into thin slips, and put them into a matrass placed in a very hot sand-bath. When the matter is liquefied, add the linseed-oil in a state of ebullition, and then the essence warm. When the varnish has lost a great part of its heat, strain it through a piece of linen, and preserve it in a wide-mouthed bottle. This varnish dries very slowly, a fault which is owing to the peculiar nature of the caoutchouc.

The invention of air balloons led to the idea of applying caoutchouc to the composition of varnish. It was necessary to have a varnish which should unite great pliability and consistence. No varnish seemed capable of corresponding to these views, except that of caoutchouc, but the desiccation of it is exceedingly tedious.

To make varnish for silks, &c.—To one quart of cold-drawn linseed-oil, poured off from the lees, (produced on the addition of unslacked lime, on which the oil has stood eight or ten days at the least, in order to communicate a drying quality,—or brown umber, burnt and powdered, which will have the like effect,) and half an ounce of litharge; boil them for half an hour, then add half an ounce of the copal varnish. While the ingredients are on the fire, in a copper vessel, put in one ounce of chios turpentine, or common resin, and a few drops of neatsfoot-oil, and stir the whole with a knife; when cool, it is ready for use. The neatsfoot-oil prevents the varnish from being sticky or adhesive, and may be put into the linseed-oil at the same time with the lime, or burnt umber. Resin or chios turpentine may be added, till the varnish has attained the desired thickness.

The longer the raw linseed-oil remains on the unslacked lime or umber, the sooner will the oil dry after it is used; if some months, so much the better: such varnish will set, that is to say, not run, but keep its place on the silk in four hours; the silk may then be turned, and varnished on the other side.

To make pliable varnish for umbrellas.—Take any quantity of caoutchouc, as ten or twelve ounces, cut into small bits with a pair of scissors, and put a strong iron ladle, (such as that in which painters, plumbers, or glaziers melt their lead,) over a common pit-coal or other fire; which must be gentle, glowing, and without smoke. When the ladle is hot, put a single bit into it: if black smoke issues, it will presently flame and disappear, or it will evaporate without flame; the ladle is then too hot. When the ladle is less hot, put in a second bit, which will produce a white smoke; this white smoke will continue during the operation, and evaporate the caoutchouc; therefore no time is to be lost, but little bits are to be put in, a few at a time, till the whole are melted; it should be continually and gently stirred with an iron or brass spoon. The instant the smoke changes from white to black, take off the ladle, or the whole will break out into a violent flame, or be spoiled, or lost. Care must be taken that no water be added, a few drops only of which would, on account of its expansibility, make it boil over furiously and with great noise; at this period of the process, 2 pounds or 1 quart of the best drying oil is to be put into the melted caoutchouc, and stirred till hot, and the whole poured into a glazed vessel through a coarse gauze, or wire sieve. When settled and clear, which will be in a few minutes, it is fit for use, either hot or cold.

The silk should be always stretched horizontally by pins or tenterhooks on frames: (the greater they are in length the better,) and the varnish poured on *cold in hot weather*, and *hot in cold weather*. It

is perhaps best always to lay it on when cold. The art of laying it on properly, consists in making no intestine motion in the varnish, which would create minute bubbles, therefore brushes of every kind are improper, as each bubble breaks in drying, and forms a small hole, through which the air will transpire.

This varnish is pliant, unadhesive, and unalterable by weather.

Varnish used for Indian shields.—Shields made at Silhet, in Bengal, are noted throughout India for the *lustre and durability of the black varnish* with which they are covered; Silhet shields constitute, therefore, no inconsiderable article of traffic, being in request among natives who carry arms, and retain the ancient predilection for the scimitar and buckler. The varnish is composed of the expressed juice of the marking nut, *Semecarpus Anacardium*, and that of another kindred fruit, *Holigarna Longifolia*.

The shell of the *Semecarpus Anacardium* contains between its integuments numerous cells, filled with a black, acrid, resinous juice; which likewise is found, though less abundantly, in the wood of the tree. It is commonly employed as an indelible ink, to mark all sorts of cotton cloth. The colour is fixed with quick lime. The cortical part of the fruit of *Holigarna Longifolia* likewise contains between its laminæ numerous cells, filled with a black, thick, acrid fluid. The natives of Malabar extract by incision, with which they varnish targets.

To prepare the varnish according to the method practised in Silhet, the nuts of the *Semecarpus Anacardium*, and the berries of the *Holigarna Longifolia*, having been steeped for a month in clear water, are cut transversely, and pressed in a mill. The expressed juice of each is kept for several months, taking off the scum from time to time. Afterwards the liquor is decanted, and two parts of the one are added to one part of the other, to be used as varnish. Other proportions of ingredients are sometimes employed: but in all the resinous juice of the *Semecarpus* predominates. This varnish is laid on like paint, and when dry is polished by rubbing it with an agate, or smooth pebble. This varnish also prevents destruction of wood, &c. by the *white ant*.

To give a drying quality to poppy-oil.

3 lb. of pure water,
1 oz. of sulphate of zinc, (white vitriol,) and
2 lb. of oil of pinks, or poppy-oil.

Expose this mixture in an earthen vessel capable of standing the fire, to a degree of heat sufficient to maintain it in a slight state of ebullition. When one-half or two-thirds of the water has evaporated, pour the whole into a large glass bottle or jar, and leave it at rest till the oil becomes clear. Decant the clearest part by means of a glass funnel, the beak of which is stopped by a piece of cork: when the separation of the oil from the water is completely effected, remove the cork stopper, and supply its place by the fore-finger, which must be applied in such a manner as to suffer the water to escape, and to retain only the oil.

Poppy-oil when prepared in this manner becomes, after some weeks, exceedingly limpid and colourless.

To give a drying quality to fat oils.

No. 1.—8 lb. nut-oil, or linseed-oil,
1 oz. white lead, slightly calcined,
1 oz. yellow acetate of lead, (sal saturni,) also calcined,
1 oz. sulphate of zinc, (white vitriol,)
12 oz. vitreous oxide of lead, (litharge,) and
a head of garlic, or a small onion.

When the dry substances are pulverized, mix them with the garlic and oil, over a fire capable of maintaining the oil in a slight state of ebullition: continue it till the oil ceases to throw up scum, till it assumes a reddish colour, and till the head of garlic becomes brown. A pellicle will then be soon formed on the oil, which indicates that the operation is completed. Take the vessel from the fire, and the pellicle, being precipitated by rest, will carry with it all the unctuous parts which rendered the oil fat. When the oil becomes clear, separate it from the deposit, and put it into wide-mouthed bottles, where it will completely clarify itself in time, and improve in quality.

No. 2.—1½ oz. of vitreous oxide of lead, (litharge,)
⅝ oz. sulphate of zinc, (white vitriol,) and
16 oz. linseed, or nut-oil.

The operation must be conducted as in the preceding case.

The choice of the oil is not a matter of indifference. If it be destined for painting articles exposed to the impression of the external air, or for delicate painting, nut-oil or poppy-oil will be requisite. Linseed-oil is used for coarse painting, and that sheltered from the effects of the rain and of the sun.

A little negligence in the management of the fire has often an influence on the colour of the oil, to which a drying quality is communicated; in this case it is not proper for delicate painting. This inconvenience may be avoided by tying up the drying matters in a small bag; but the dose of the litharge must then be doubled. The bag must be suspended by a piece of pack-thread fastened to a stick, which is made to rest on the edge of the vessel in such a manner as to keep the bag at the distance of an inch from the bottom of the vessel. A pellicle will be formed as in the first operation, but it will be slower in making its appearance.

No. 3.—A drying quality may be communicated to oil by treating, in a heat capable of maintaining a slight ebullition, linseed, or nut-oil, to each pound of which is added 3 oz. of vitreous oxide of lead, (litharge,) reduced to fine powder.

The preparation of floor-cloths, and all paintings of large figures or ornaments, in which argillaceous colours, such as yellow and red boles, Dutch pink, &c. are employed, require this kind of preparation, that the desiccation may not be too slow; but painting for which metallic oxides are used, such as preparations of lead, copper, &c. require only the doses before indicated, because these oxides contain

a great deal of oxygen, and the oil, by their contact, acquires more of a drying quality.

No. 4.—2 lbs. of nut-oil,
3 lbs. of common water, and
2 oz. of sulphate of zinc, (white vitriol.)

Mix these matters, and subject them to a slight ebullition, till little water remains. Decant the oil, which will pass over with a small quantity of water, and separate the latter by means of a funnel. The oil remains nebulous for some time; after which it becomes clear, and seems to be very little coloured.

No. 5.—6 lbs. of nut-oil, or linseed-oil,
4 lbs. of common water,
1 oz. of sulphate of zinc, and
1 head of garlic.

Mix these matters in a large iron or copper pan; then place them over the fire, and maintain the mixture in a state of ebullition during the whole day: boiling water must from time to time be added to make up for the loss of that by evaporation. The garlic will assume a brown appearance. Take the pan from the fire, and having suffered a deposit to be formed, decant the oil, which will clarify itself in the vessels. By this process the drying oil is rendered somewhat more coloured: it is reserved for delicate colours.

Resinous drying oil.—Take 10 lbs. of drying nut-oil, if the paint is destined for external, or 10 lbs. of drying linseed-oil, if for internal articles.

3 lbs. of resin, and
6 oz. of turpentine.

Cause the resin to dissolve the oil by means of a gentle heat. When dissolved and incorporated with the oil, add the turpentine: leave the varnish at rest, by which means it will often deposit portions of resin and other impurities; and then preserve it in wide-mouthed bottles. It must be used fresh; when suffered to grow old it abandons some of its resin. If this resinous oil assumes too much consistence, dilute it with a little essence, if intended for articles sheltered from the sun, or with oil of poppies.

In Switzerland, where the principal part of the mason's work consists of stones subject to crumble to pieces, it is often found necessary to give them a coating of oil paint, to stop the effects of this decomposition. This painting has a great deal of lustre, and when the last coating is applied with resinous oil, it has the effect of a varnish. To give it more durability, the first ought to be applied exceedingly warm and with plain oil, or oil very little charged with the grey colour, which is added to the two following:

Fat copal varnish.

16 oz. of picked copal,
8 oz. of prepared linseed oil, or oil of poppies, and
16 oz. of essence of turpentine.

Liquefy the copal in a matrass over a common fire, and then add the linseed-oil, or oil of poppies, in a state of ebullition; when these

matters are incorporated, take the matrass from the fire, stir the matter till the greatest heat is subsided, and then add the essence of turpentine warm. Strain the whole, while still warm, through a piece of linen, and put the varnish into a wide-mouthed bottle. Time contributes towards its clarification; and in this manner it acquires a better quality.

Varnish for watch-cases, in imitation of tortoise-shell.

6 oz. of copal of an amber colour,
1½ oz. Venice turpentine,
24 oz. prepared linseed-oil, and
6 oz. essence of turpentine.

It is customary to place the turpentine over the copal, reduced to small fragments, in the bottom of an earthen or metal vessel, or in a matrass exposed to such a heat as to liquefy the copal: but it is more advantageous to liquefy the latter alone, to add the oil in a state of ebullition, then the turpentine liquefied, and in the last place, the essence. If the varnish is too thick, some essence may be added. The latter liquor is a regulator for the consistence in the hands of an artist.

To make a colourless copal varnish.—As all copal is not fit for this purpose, in order to ascertain such pieces as are good, each must be taken separately, and a single drop of pure essential oil of rosemary, not altered by keeping, must be let fall on it. Those pieces which soften at the part that imbibes the oil are good; reduce them to powder, which sift through a very fine hair sieve, and put it into a glass, on the bottom of which it must not lie more than a finger's breadth thick. Pour upon it essence of rosemary to a similar height; stir the whole for a few minutes, when the copal will dissolve into a viscous fluid. Let it stand for two hours, and then pour gently on it two or three drops of very pure alcohol, which distribute over the oily mass by inclining the bottle in different directions with a very gentle motion. Repeat this operation by little and little, till the incorporation is effected, and the varnish reduced to a proper degree of fluidity. It must then be left to stand a few days, and, when very clear, be decanted off. This varnish, thus made without heat, may be applied with equal success to pasteboard, wood, and metals, and takes a better polish than any other. It may be used on paintings, the beauty of which it greatly heightens.

Gold-coloured copal varnish.

1 oz. copal in powder,
2 oz. essential oil of lavender, and
6 oz. essence of turpentine.

Put the essential oil of lavender into a matrass of a proper size, placed on a sand-bath, heated by an Argand's lamp, or over a moderate coal-fire. Add to the oil while very warm, and at several times, the copal powder, and stir the mixture with a stick of white wood, rounded at the end. When the copal has entirely disappeared, add at three different times the essence almost in a state of ebullition, and keep continually stirring the mixture. When the solution is

completed, the result will be a varnish of a gold colour, exceedingly durable and brilliant, but less drying than the preceding.

No. 2.—To obtain this varnish colourless, it will be proper to rectify the essence of the shops, which is often highly coloured, and to give it the necessary density by exposure to the sun in bottles closed with cork stoppers, leaving an interval of some inches between the stopper and the surface of the liquid. A few months are thus sufficient to communicate to it the required qualities. Besides, the essence of the shops is rarely possessed of that state of consistence, without having at the same time a strong amber colour.

The varnish resulting from the solution of copal in oil of turpentine, brought to such a state as to produce the maximum of solution, is exceedingly durable and brilliant. It resists the shock of hard bodies much better than the enamel of toys, which often become scratched and whitened by the impression of repeated friction; it is applied with the greatest success to philosophical instruments, and the paintings with which vessels and other utensils of metal are decorated.

No. 3.—4 oz. copal, and
1 oz. clear turpentine.

Put the copal, coarsely pulverized, into a varnished pot, and give it the form of a pyramid, which must be covered with turpentine. Shut the vessel closely, and placing it over a gentle fire, increase the heat gradually, that it may not attack the copal; as soon as the matter is well liquefied, pour it upon a plate of copper, and when it has resumed its consistence reduce it to powder.

Put half an ounce of this powder into a matrass with four ounces of the essence of turpentine, and stir the mixture till the solid matter is entirely dissolved.

Camphorated copal varnish.—This varnish is destined for articles which require durability, pliableness, and transparency, such as the varnished wire-gauze, used in ships instead of glass.

2 oz. of pulverized copal,
6 oz. of essential oil of lavender,
⅛ of an oz. of camphor, and
essence of turpentine, a sufficient quantity, according to the consistence required to be given to the varnish.

Put into a phial of thin glass, or into a small matrass, the essential oil of lavender and the camphor, and place the mixture on a moderately open fire, to bring the oil and the camphor to a slight state of ebullition; then add the copal powder in small portions, which must be renewed as they disappear in the liquid. Favour the solution by continually stirring it with a stick of white wood; and when the copal is incorporated with the oil, add the essence of turpentine boiling: but care must be taken to pour in, at first, only a small portion.

This varnish is little coloured, and by rest it acquires a transparency which, united to the solidity observed in almost every kind of copal varnishes, renders it fit to be applied with great success in many

cases, and particularly in the ingenious invention of substituting varnished metallic gauze in the room of Muscovy talc, a kind of mica, in large laminæ, used for the cabin windows of ships, as presenting more resistance to the concussion of the air during the firing of the guns. Varnished metallic gause of this kind is manufactured at Rouen.

Ethereal copal varnish.—½ oz. of amberry copal, and
2 oz. of ether.

Reduce the copal to a very fine powder, and introduce it by small portions into the flask which contains the ether; close the flask with a glass or cork stopper, and having shaken the mixture for half an hour, leave it at rest till the next morning. In shaking the flask, if the sides become covered with small undulations, and if the liquor be not exceedingly clear, the solution is not complete. In this case, add a little ether, and leave the mixture at rest. The varnish is of a light lemon colour. The largest quantity of copal united to ether may be a fourth and the least a fifth. The use of copal varnish made with ether, seems, by the expense attending it, to be confined to repairing those accidents which frequently happen to the enamel of toys, as it will supply the place of glass to the coloured varnishes, employed for mending fractures, or to restoring the smooth surface of paintings which have been cracked and shattered.

The great volatility of ether, and in particular its high price, do not allow the application of this varnish to be recommended, but for the purpose here indicated. It has been applied to wood with complete success, and the glazing it produced, united lustre to solidity. In consequence of the too speedy evaporation of the liquid, it often boils under the brush. Its evaporation, however, may be retarded, by spreading over the wood a slight stratum of essential oil of rosemary, or lavender, or even of turpentine, which may afterwards be removed by a piece of linen rag; what remains is sufficient to retard the evaporation of the ether.

Turpentine copal varnish.

1½ oz. of copal, of an amber colour, and in powder, and
8 oz. of best oil of turpentine.

Expose the essence to a balneum mariæ, in a wide-mouthed matrass with a short neck; as soon as the water of the bath begins to boil, throw into the essence a large pinch of copal powder, and keep the matrass in a state of circular motion. When the powder is incorporated with the essence, add new doses to it; and continue in this manner till you observe that there is formed an insoluble deposit. Then take the matrass from the bath, and leave it at rest for some days. Draw off the clear varnish, and filter it through cotton.

At the moment when the first portion of the copal is thrown into the essence, if the powder precipitate itself under the form of lumps, it is needless to proceed any further. This effect arises from two causes: either the essence does not possess the proper degree of concentration, or it has not been sufficiently deprived of water. Exposure to the sun, employing the same matrass, to which a cork

stopper ought to be added, will give it the qualities requisite for the solution of the copal. This effect will be announced by the disappearance of the portion of copal already put into it.

Another copal varnish.

3 oz. of copal, liquefied, and
20 oz. of essence of turpentine.

Place the matrass containing the oil in a balneum mariæ, and when the water boils add the pulverized copal in small doses. Keep stirring the mixture, and add no more copal till the former be incorporated with the oil. If the oil, in consequence of its particular disposition, can take up three ounces of it, add a little more; but stop, if the liquid becomes nebulous, and leave the varnish at rest. If it be too thick, dilute it with a little warm essence, after having heated it in the balneum mariæ. When cold, filter it through cotton, and preserve it in a clean bottle.

This varnish has a good consistence, and is as free from colour as the best alcoholic varnish. When extended in one stratum over smooth wood, which has undergone no preparation, it forms a very brilliant glazing, which, in the course of two days, in summer, acquires all the solidity that may be required.

The facility which attends the preparation of this varnish by the new method here indicated, will admit of its being applied to all coloured grounds which require solidity, pure whites alone excepted; painted boxes, therefore, and all small articles, coloured or not coloured, whenever it is required to make the veins appear in all the richness of their tones, call for the application of this varnish, which produces the most beautiful effect, and which is more durable than turpentine varnishes composed with other resinous substances.

Fat amber varnish.

16 oz. of amber, coarsely powdered,
2 oz. of Venice turpentine, or gum lac,
10 oz. of prepared linseed-oil, and
16 oz. of essence of turpentine.

The circumstances of the process are the same as those prescribed for the preparation of the camphorated copal varnish.

This varnish was formerly much used; but it has given place, in part, to that of copal, which is preferred on account of its being less coloured. Watin introduces more essence and less linseed-oil; experience and long practice are the only authority on which I recommend the adoption of the present formula.

Amber varnish with essence of turpentine.

6 or 7 oz. of liquefied amber, and separated from the oily portions which alter its consistence.

Reduce the amber to powder, and if the operation of pounding forms it into a paste, break it with your fingers: then mix it with the essence, and heat the whole in a balneum mariæ. It will speedily dissolve, and the essence will take up, at the least, a fourth part of its weight of the prepared amber.

When one coating of it is applied to white smooth wood, but

without any preparation, it forms a very pure and very durable glazing, which speedily dries, but slower than copal varnish.

Fat amber, or copal varnish.

4 oz. of amber or copal, of one fusion,
10 oz. of essence of turpentine, and
10 oz. of drying linseed-oil.

Put the whole into a pretty large matrass, and expose it to the heat of a balneum mariæ, or move it over the surface of an uncovered chaffing-dish, but without flame, and at the distance from it of two or three inches. When the solution is completed, add still a little copal or amber to saturate the liquid; then pour the whole on a filter prepared with cotton, and leave it to clarify by rest. If the varnish is too thick, add a little warm essence to prevent the separation of any of the amber.

This varnish is coloured, but far less so than those composed by the usual methods. When spread over white wood, without any preparation, it forms a solid glazing, and communicates a slight tint to the wood.

If it be required to charge this varnish with more copal, or prepared amber, the liquid must be composed of two parts of essence for one of oil.

Compound mastic varnish.

32 oz. of pure alcohol,
6 oz. of purified mastic,
3 oz. of gum sandarac,
3 oz. of very clear Venice turpentine, and
4 oz. of glass, coarsely pounded.

Reduce the mastic and sandarac to fine powder; mix this powder with white glass, from which the finest parts have been separated by means of a hair sieve; put all the ingredients, with alcohol, into a short-necked matrass, and adapt to it a stick of white wood, rounded at the end, and of a length proportioned to the height of the matrass, that it may be put in motion. Expose the matrass in a vessel filled with water, made at first a little warm, and which must afterwards be maintained in a state of ebullition for one or two hours. The matrass may be made fast to a ring of straw.

When the solution seems to be sufficiently extended, add the turpentine, which must be kept separately in a phial or a pot, and which must be melted, by immersing it for a moment in a balneum mariæ. The matrass must be still left in the water for half an hour, at the end of which it is taken off; and the varnish is continually stirred till it is somewhat cool. Next day it is to be drawn off, and filtered through cotton. By these means it will become exceedingly limpid.

The addition of glass may appear extraordinary; but this substance divides the parts of the mixture, which have been made with the dry ingredients, and it retains the same quality when placed over the fire. It therefore obviates with success two inconveniences, which are exceedingly troublesome to those who compose varnishes. In the first place, by dividing the matters, it facilitates the action of the

alcohol; and in the second its weight, which surpasses that of resins, prevents these resins from adhering to the bottom of the matrass, and also the coloration acquired by the varnish when a sand-bath is employed, as is commonly the case.

The application of this varnish is suited to articles belonging to the toilette, such as dressing-boxes, cut paper-works, &c. The following possess the same brilliancy and lustre; but they have more solidity, and are exceedingly drying.

Camphorated mastic varnish for paintings.

12 oz. of mastic, cleaned and washed.
1½ oz. of pure turpentine,
½ oz. of camphor,
5 oz. of white glass, pounded, and
36 oz. of etherous essence of turpentine.

Make the varnish according to the method indicated for compound mastic varnish of the first genus. The camphor is employed in pieces, and the turpentine is added when the solution of the resin is completed. But if the varnish is to be applied to old paintings, or paintings which have been already varnished, the turpentine may be suppressed, as this ingredient is here recommended only in cases of a first application to new paintings, and just freed from white of egg varnish.

The etherous essence recommended for varnish, is that distilled slowly, without any intermediate substance, according to the second process already given for its rectification.

The question by able masters, respecting the kind of varnish proper to be employed for paintings, has never yet been determined.

Some artists, who have paid particular attention to this object, make a mystery of the means they employ to obtain the desired effect. The real end may be accomplished by giving to the varnish, destined for painting, pliability and softness, without being too solicitous in regard to what may add to its consistence or its solidity. The latter quality is particularly requisite in varnishes which are to be applied to articles much exposed to friction, such as boxes, furniture. &c.

To make painter's cream.—Painters, who have long intervals between their periods of labour, are accustomed to cover the parts they have painted with a preparation which preserves the freshness of the colours, and which they can remove when they resume their work. This preparation is as follows:

3 oz. very clear nut-oil,
½ oz. mastic in tears, pulverized, and
½ oz. sal. saturni, in powder, (acetate of lead.)

Dissolve the mastic oil over a gentle fire, and pour the mixture into a marble mortar, over the pounded salt of lead; stir it with a wooden pestle, and add water in small quantities, till the matter assume the appearance and consistence of cream, and refuse to admit more water.

Sandarac varnish.

8 oz. gum sandarac,

2 oz. pounded mastic,
4 oz. clear turpentine,
4 oz. pounded glass, and
32 oz. alcohol.

Mix, and dissolve as before.

Compound sandarac varnish.

3 oz. pounded copal of an amber colour, once liquefied,
6 oz. gum sandarac,
3 oz. mastic, cleaned,
2½ oz. clear turpentine,
4 oz. pounded glass, and
32 oz. pure alcohol.

Mix these ingredients, and pursue the same method as above.

This varnish is destined for articles subject to friction, such as furniture, chairs, fan-sticks, mouldings, &c. and even metals, to which it may be applied with success. The sandarac gives it great durability.

Camphorated sandarac varnish for cut paper-works, dressing-boxes, &c.

No. 1.—6 oz. gum sandarac,
4 oz. gum elemi,
1 oz. gum anima,
½ oz. camphor,
4 oz. pounded glass, and
32 oz. pure alcohol.

Make the varnish according to the directions already given. The soft resins must be pounded with the dry bodies. The camphor is to be added in pieces.

No. 2.—6 oz. gallipot, or white incense,
2 oz. gum anima,
2 oz. pounded glass, and
32 oz. alcohol.

Make the varnish with the precautions indicated for the compound mastic varnish.

The two last varnishes are to be used for ceilings and wainscots, coloured or not coloured : they may even be employed as a covering to parts painted with strong colours.

Spirituous sandarac varnish for wainscotting, small articles of furniture, balustrades, and inside railing.

No. 1.—6 oz. of gum sandarac,
2 oz. of shell lac,
4 oz. of colophonium, or resin,
4 oz. of white glass powdered,
4 oz. of clear turpentine, and
32 oz. of pure alcohol.

Dissolve the varnish according to the directions given for compound mastic varnish.

This varnish is sufficiently durable to be applied to articles destined

to daily and continual use. Varnishes composed with copal ought, however, in these cases to be preferred.

No. 2.—There is another composition which, without forming part of the compound varnishes, is employed with success for giving a polish and lustre to furniture made of wood: wax forms the basis of it.

Many cabinet-makers are contented with waxing common furniture, such as tables, chest of drawers, &c. This covering, by means of repeated friction, soon acquires a polish and transparency which resembles those of varnish. Waxing seems to possess qualities peculiar to itself; but, like varnish it is attended with inconveniences as well as advantages.

Varnish supplies better the part of glazing; it gives a lustre to the wood which it covers, and heightens the colours of that destined, in particular, for delicate articles. These real and valuable advantages are counterbalanced by its want of consistence; it yields too easily to the shrinking or swelling of the wood, and rises in scales, or slits, on being exposed to the slightest shock. These accidents can be repaired only by new strata of varnish, which render application to the varnisher necessary, and occasion trouble and expense.

Waxing stands shocks; but it does not possess, in the same degree as varnish, the property of giving lustre to the bodies on which it is applied, and of heightening their tints. The lustre it communicates is dull, but this inconvenience is compensated by the facility with which any accident that may have altered its polish can be repaired, by rubbing it with a piece of fine cork. There are some circumstances, therefore, under which the application of wax ought to be preferred to that of varnish. This seems to be the case in particular with tables of walnut-tree wood, exposed to daily use, chairs, mouldings, and for all small articles subject to constant employment.

But as it is of importance to make the stratum of wax as thin as possible, in order that the veins of the wood may be more apparent, the following process will be acceptable to the reader.

Melt over a moderate fire, in a very clean vessel, two ounces of white or yellow wax; and, when liquefied, add four ounces of good essence of turpentine. Stir the whole until it is entirely cool, and the result will be a kind of pomade fit for waxing furniture, and which must be rubbed over them according to the usual method. The essence of turpentine is soon dissipated; but the wax, which by its mixture is reduced to a state of very great division, may be extended with more ease, and in a more uniform manner. The essence soon penetrates the pores of the wood, calls forth the colour of it, causes the wax to adhere better, and the lustre which thence results is equal to that of varnish, without having any of its inconveniences.

Coloured varnish for violins, and other stringed instruments, also for plum-tree, mahogany, and rose-wood.

4 oz. gum sandarac,
2 oz. seed lac,

2 oz. mastic,
1 oz. Benjamin in tears,
4 oz. pounded glass,
2 oz. Venice turpentine, and
32 oz. pure alcohol.

The gum sandarac and lac render this varnish durable : it may be coloured with a little saffron or dragon's blood.

Fat Varnish of a gold colour.

8 oz. amber,
2 oz. gum lac,
8 oz. drying linseed-oil, and
16 oz. essence of turpentine.

Dissolve separately the gum lac, and then add the amber, prepared and pulverized, with the linseed-oil and essence very warm. When the whole has lost part of its heat, mix in relative proportions, tinctures of annatto, of terra merita, gum guttæ, and dragon's blood. This varnish when applied to white metals, gives them a gold colour.

Fat turpentine or golden varnish, being a mordant to gold and dark colours.

16 oz. boiled linseed-oil,
8 oz. Venice turpentine, and
5 oz. Naples yellow.

Heat the oil with the turpentine; and mix the Naples yellow pulverized.

Naples yellow is an oxide of lead, the composition of which will be given when we come to treat of colouring substances. It is substituted here for resins, on account of its drying qualities, and in particular of its colour, which resembles that of gold ; great use is made of the varnish in applying gold leaf.

The yellow, however, may be omitted when this species of varnish is to be solid and coloured coverings. In this case an ounce of litharge to each pound of composition may be substituted in its stead, without this mixture doing any injury to the colour which is to constitute the ground, (*la teinte dure*).

Turners' varnish for box wood.

5 oz. seed lac,
2 oz. gum sandarac,
1½ oz. gum elemi,
2 oz. Venice turpentine,
5 oz. pounded glass, and
24 oz. pure alcohol.

The artists of St Claude do not all employ this formula, which required to be corrected on account of its too great dryness, which is here lessened by the turpentine and gum elemi. This composition is secured from cracking, which disfigures these boxes after they had been used for some months.

No. 2.—Other turners employ the gum lac united to a little elemi and turpentine digested some months in pure alcohol exposed to the sun. If this method be followed, it will be proper to substitute for

the sandarac, the same quantity of gum lac reduced to powder, and not to add the turpentine to the alcohol, which ought to be exceedingly pure, till towards the end of the infusion.

Solar infusion requires care and attention. Vessels of a sufficient size to allow the spirituous vapours to circulate freely ought to be employed, because it is necessary that the vessels should be closely shut. Without this precaution the spirits would become weakened, and abandon the resin which they laid hold of during the first days of exposure. This perfect obituration will not admit of the vessels being too full.

In general, the varnishes applied to articles which may be put into the lathe acquire a great deal of brilliancy by polishing; a piece of woollen cloth is sufficient for the operation. If turpentine predominates too much in these compositions, the polish does not retain its lustre, because the heat of the hands is capable of softening the surface of the varnish, and in this state it readily tarnishes.

To varnish dressing-boxes.—The most of spirit of wine varnishes are destined for covering preliminary preparations, which have a certain degree of lustre. They consist of cement, coloured or not coloured, charged with landscapes and figures cut out in paper, which produces an effect under the transparent varnish : most of the dressing-boxes, and other small articles of the same kind, are covered with this particular composition, which, in general, consists of three or four coatings of Spanish white pounded in water, and mixed up with parchment glue. The first coating is smoothed with pumice-stone, and then polished with a piece of new linen and water. The coating in this state is fit to receive the destined colour, after it has been ground with water, and mixed with parchment glue diluted with water. The cut figures with which it is to be embellished are then applied, and a coating of gum or fish-glue is spread over them, to prevent the varnish from penetrating to the preparation, and from spoiling the figures. The operation is finished by applying three or four coatings of varnish, which, when dry, are polished with tripoli and water, by means of a piece of cloth. A lustre is then given to the surface with starch and a bit of doe-skin, or very soft cloth.

Gallipot varnish.

12 oz. gallipot, or white incense,
5 oz. white glass, pounded,
2 oz. Venice turpentine, and
32 oz. essence of turpentine.

Make the varnish after the white incense has been pounded with glass.

Some authors recommend mastic or sandarac in the room of gallipot; but the varnish is neither more beautiful nor more durable. When the colour is ground with the preceding varnish, and mixed up with the latter, which, if too thick, is thinned with a little essence, and which is applied immediately, and without any sizing, to boxes and other articles, the coatings acquire sufficient strength to resist the blows of a mallet. But if the varnish be applied to a sized colour, it must be covered with a varnish of the first or second genus.

Mastic gallipot varnish, for grinding colours.

4 oz. new gallipot, or white incense,
2 oz. mastic,
6 oz. Venice turpentine,
4 oz. pounded glass, and
32 oz. essence of turpentine.

When the varnish is made with the precautions already indicated, add prepared nut oil or linseed-oil two ounces.

The matters ground with this varnish dry more slowly; they are then mixed up with the following varnish, if it be for common painting, or with particular varnishes destined for colours and for grounds.

Mordant varnish for gilding.

1 oz of mastic,
1 oz. of gum sandarac,
½ oz. of gum guttæ,
¼ oz. of turpentine, and
6 oz. of essence of turpentine.

Some artists who make use of mordants, substitute for the turpentine an ounce of the essence of lavender, which renders this composition still less drying.

In general, the composition of mordants admits of modifications, according to the kind of work for which they are destined. The application of them, however, is confined chiefly to gold. When it is required to fill up a design with gold leaf on any ground whatever, the composition which is to serve as the means of union between the metal and the ground, ought to be neither too thick nor too fluid; because both these circumstances are equally injurious to delicacy in the strokes; it will be requisite also that the composition should not dry till the artist has completed his design.

Other mordants. No 1.—Some prepare their mordants with Jew's pitch and drying oil, diluted with essence of turpentine. They employ it for gilding pale gold, or for bronzing.

Other artists imitate the Chinese, and mix with their mordants colours proper for assisting the tone which they are desirous of giving to the gold, such as yellow, red, &c.

Others employ merely fat varnish, to which they add a little red oxide of lead (minium.)

Others make use of thick glue, in which they dissolve a little honey. This is what they call *batture.* When they are desirous of heightening the colour of the gold, they employ this glue, to which the gold leaf adheres exceedingly well.

No. 2.—The qualities of the following are fit for every kind of application, and particularly to metals. Expose boiled oil to a strong heat in a pan: when a black smoke is disengaged from it, set it on fire, and extinguish it a few moments after by putting on the cover of the pan. Then pour the matter, still warm, into a heated bottle, and add to it a little essence of turpentine. This mordant dries very speedily; it has body and adheres to, and strongly retains, gold leaf, when applied to wood, metals, and other substances.

Varnish for pales and coarse wood-work.—Take any quantity of tar, and grind it with as much Spanish brown as it will bear, without rendering it too thick to be used as a paint or varnish, and then spread it on the pales, or other wood, as soon as convenient, for it quickly hardens by keeping.

This mixture must be laid on the wood to be varnished by a large brush, or house painter's tool; and the work should then be kept as free from dust and insects as possible, till the varnish be thoroughly dry. It will, if laid on smooth wood, have a very good gloss, and is an excellent preservation of it against moisture; on which account, as well as its being cheaper, it is far preferable to painting, not only for pales, but for weather-boarding, and all other kinds of wood-work for grosser purposes. Where the glossy brown colour is not liked, the work may be made of a greyish brown, by mixing a small proportion of white lead, or whiting and ivory black, with the Spanish brown.

A black varnish for old straw or chip hats.

½ oz. of best blark sealing wax, and
2 oz. of rectified spirit of wine.

Powder the sealing wax, and put it with the spirit of wine into a four-ounce phial; digest them in a sand heat, or near a fire, till the wax is dissolved; lay it on warm with a fine soft hair-brush, before a fire or in the sun. It gives a good stiffness to old straw hats, and a beautiful gloss, equal to new, and resists wet.

To make varnish for coloured drawings.

1 oz. of Canada balsam, and
2 oz. of spirit of turpentine.—Mix them together.

Before this composition is applied, the drawing or print should be sized with a solution of isinglass in water; and when dry, apply the varnish with a camel's-hair brush.

To make varnish for wood, which resists the action of boiling water.—Take a pound and a half of linseed-oil, and boil it in a red copper vessel, not tinned, holding suspended over it, in a small linen bag, 5 oz. of litharge, and 3 oz. of pulverized minium, taking care that the bag does not touch the bottom of the vessel. Continue the ebullition until the oil acquires a deep brown colour; then take away the bag, and substitute another in its place, containing a clove of garlic; continue the ebullition, and renew the clove of garlic seven or eight times, or rather put them all in at once.

Then throw into the vessel a pound of yellow amber, after having melted it in the following manner:—Add to the pound of amber, well pulverized, two ounces of linseed-oil, and place the whole on a strong fire. When the fusion is complete, pour it boiling into the prepared linseed-oil, and continue to leave it boiling for two or three minutes, stirring the whole up well. It is then left to settle; the composition is decantered and preserved, when it becomes cold, in well-corked bottles.

After polishing the wood on which this varnish is to be applied, give to the wood the colour required; for instance, for walnut wood, a slight coat of a mixture of soot with the essence of turpentine.

When this colour is prefectly dry, give it a coat of varnish with a fine sponge, in order to spread it very equal; repeat these coats four times, taking care always to let the preceding coat be dried.

To varnish drawings and card-work.—Boil some clear parchment cuttings in water, in a glazed pipkin, till they produce a very clear size. Strain it, and keep it for use.

Give the work two coats of the size, passing the brush quickly over the work, not to disturb the colours.

To prepare a composition for making coloured drawings and prints resemble paintings in oil.

1 oz. of Canada balsam, and
2 oz. of spirits of turpentine.—Mixt together.

Before this composition is applied, the drawing or print should be sized with a solution of isinglass in water, and when dry, apply the varnish with a camel's-hair brush.

To varnish harps and dulcimers.—Prepare the work with size and red ochre, then take ochre, burnt umber, and red lead, well ground, and mix up a dark brown colour in turpentine varnish, adding as much oil of turpentine that the brush may just be able to pass over the work fair and even. While yet wet, take a muslin sieve, and sift as much Dutch metal, previously powdered, upon it, as is requisite to produce the effect, after which varnish and polish it.

To varnish glass.—Pulverize a quantity of gum adragant, and let it dissolve for twenty-four hours in the white of eggs well beat up; then rub it gently on the glass with a bush.

To varnish balloons. No. 1.—The compositions for varnishing balloons have been variously modified; but, upon the whole, the most approved appears to be the bird-lime varnish of M. Faujas St Fond, prepared after M. Cavallo's method as follows: "In order to render linseed oil drying, boil it with 2 ounces of sugar of lead, and 3 ounces of litharge, for every pint of oil, till they are dissolved, which may be in half an hour. Then put a pound of bird-lime, and half a pint of the drying oil, into an iron or copper vessel whose capacity should equal about a gallon, and let it boil very gently over a slow charcoal fire till the bird-lime ceases to crackle, which will be in about half, or three-quarters of an hour; then pour upon it two and a half pints more of the drying oil, and let it boil about an hour longer, stirring it frequently with an iron or wooden spatula. As the varnish, whilst boiling, and especially when nearly ready, swells very much, care should be taken to remove in those cases, the pot from the fire, and to replace it when the varnish subsides; otherwise it will boil over. Whilst the stuff is boiling, the operator should occasionally examine whether it has boiled enough, which may be known by observing whether, when rubbed between two knives, which are then to be separated from one another, the varnish forms threads between them, as it must then be removed from the fire. When nearly cool, add about an equal quantity of oil of turpentine. In using the varnish, the stuff must be stretched, and the varnish applied luke warm. In 24 hours it will dry."

No. 2. As the elastic resin, known by the name of Indian rubber, has been much extolled for a varnish, the following method of making it, as practised by M. Blanchard, may not prove, unacceptable.—Dissolve elastic gum, cut small, in five times its weight of rectified essential oil of turpentine, by keeping them some days together; then boil 1 ounce of this solution in 8 ounces of drying linseed-oil for a few minutes; strain the solution, and use it warm.

To varnish rarefied air balloons.—With regard to the rarefied-air machines, M. Cavallo recommends, first, to soak the cloth in a solution of sal-ammoniac and common size, using one pound of each to every gallon of water; and when the cloth is quite dry, to paint it over on the inside with some earthy colour and strong size or glue. When this paint has dried perfectly, it will then be proper to cover it with oily varnish, which might dry before it could penetrate quite through the cloth. Simple drying linseed-oil will answer the purpose as well as any, provided it be not very fluid.

To paint sail-cloth, &c. so as to be pliant, durable, and impervious to water.—This process, which is extracted from the *Transactions of the Society of Arts*, is now universally practised in the public dock-yards.

The paint usually laid upon canvas hardens to such a degree as to crack, and eventually to break the canvas, which renders it unserviceable in a short time: but the canvas painted in the new manner is so superior, that all canvas used in the navy is thus prepared; and a saving of a guinea is made in every one hundred square yards of canvas so painted.

The old mode of painting canvas, was to wet the canvas, and prime it with Spanish brown; then to give it a second coat of a chocolate colour, made by mixing Spanish brown and black paint: and, lastly, to finish it with black.

The new method is to grind 96 lbs. of English ochre with boiled oil, and to add 16 lbs. of black paint, which mixture forms an indifferent black. A pound of yellow soap dissolved in six pints of water over the fire, is mixed, while hot, with the paint. This composition is then laid upon the canvas, (without being wetted, as in the usual way,) as stiff as can conveniently be done with the brush, so as to form a smooth surface; the next day, or still better, on the second day, a second coat of ochre and black, (without any, or but a very small portion of soap,) is laid on, and allowing this coat an intermediate day for drying, the canvas is then finished with black paint as usual. Three days being then allowed for it to dry and harden, it does not stick together when taken down and folded in cloths containing 60 or 70 yards each; and canvas finished entirely with the composition, leaving it to dry one day between each coat, will not stick together, if laid in quantities.

It has been ascertained from actual trials, that the solution of yellow soap is a preservative to red, yellow, and black paints, when ground in oil and put into casks, as they acquire no improper hard-

ness, and dry in a remarkable manner when laid on with the brush, without the use of the usual drying articles.

It is surprising that the adoption of soap, which is so well known to be miscible with oily substances, or, at least, the alkali of which it is composed, has not already been brought into use in the composition of oil colours.

Coloured compositions for rendering linen and cloth impenetrable to water.—Begin by washing the stuff with hot water; then dry and rub it between the hands until such time as it becomes perfectly supple; afterwards spread it out by drawing it into a frame, and give it, with the aid of a brush, a first coat, composed of a mixture of eight quarts of boiling linseed-oil, 15 *grammes* of calcined amber and acetate of lead, (of each 7½ *grammes,*) to which add 90 *grammes* of lamp-black. For the second coat use the same ingredients as above, except the calx of lead. This coat will give a few hours, according to the season; afterwards take a dry plasterer's brush, and rub the stuff strongly with it, when the hair, by this operation, will become very smooth. The third and last coat will give a perfect and durable jet black.

Or rather take 12 quarts of boiling linseed-oil, 30 *grammes* of amber, 15 *grammes* of acetate of lead, 7½ sulphate of zinc, 15 Prussian blue, and 7½ verdigris; mix them very fine with a little oil, and add 120 *grammes* of lamp-black. These coats are used at discretion, as is done with painting.

To thicken linen cloth for screens and bed testers.—Grind whiting with zinc, and to prevent cracking, add a little honey to it; then take a soft brush, and lay it upon the cloth, and so do two or three times, suffering it in the mean while to dry between layings on and for the last laying, smooth it over with Spanish white, ground with linseed-oil, the oil being first heated, and mixed with a small quantity of the litharge of gold, the better to endure the weather, and so it will be lasting.

Common wax, or varnished cloth.—The manufacture of this kind of cloth is very simple. The cloth and linseed-oil are the principal articles required for the establishment. Common canvas, of an open and coarse texture, is extended on large frames, placed under sheds, the sides of which are open, so as to afford a free passage to the external air. The manner in which the cloth is fastened to these frames is as follows: it is fixed to each side of the frame, by hooks which catch the edge of the cloth, and by pieces of strong packthread passing through holes at the other extremity of the hooks, which are tied round movable pegs placed in the lower edge of the frame. The mechanism by which the strings of a violin are stretched or unstretched, will give some idea of the arrangement of the pegs employed for extending the cloth in this apparatus. By these means the cloth can be easily stretched or relaxed, when the oily varnish has exercised an action on its texture in the course of the operation. The whole being thus arranged, a liquid paste made with drying oil, which may be varied at pleasure, is applied to the cloth.

To make liquid paste with drying oil.—Mix Spanish white or tobacco-pipe clay, or any other argillaceous matter, with water, and leave it at rest some hours, which will be sufficient to separate the argillaceous parts, and to produce a sediment. Stir the sediment with a broom, to complete the division of the earth; and after it has rested some seconds, decant the turbid water into an earthen or wooden vessel. By this process the earth will be separated from the sand and other foreign bodies, which are precipitated, and which must be thrown away. If the earth has been washed by the same process, on a large scale, it is divided by kneading it. The supernatant water is thrown aside, and the sediment placed, in sieves, on pieces of cloth, where it is suffered to drain: it is then mixed up with oil rendered drying by a large dose of litharge, that is about a fourth of the weight of the oil. The consistence of thin paste being given to the mixture, it is spread over the cloth by means of an iron spatula, the length of which is equal to that of the breadth of the cloth. This spatula performs the part of a knife, and pushes forward the excess of matter above the quantity sufficient to cover the cloth. When the first stratum is dry, a second is applied. The inequalities produced by the coarseness of the cloth, or by an unequal extension of the paste, are smoothed down with pumice-stone. The pumice-stone is reduced to powder, and rubbed over the cloth with a piece of soft serge or cork dipped in water. The cloth must then be well washed in water to clean it; and after it is dried, a varnish of gum lac dissolved in linseed-oil boiled with turpentine, is to be applied to it.

This preparation produces yellowish varnished cloth. When wanted black, mix lamp-black with the Spanish white, or tobacco-pipe clay, which forms the basis of the liquid paste. Various shades of grey may be obtained, according to the quantity of lamp-black which is added. Umber, Cologne-earth, and different ochry argillaceous earths may be used to vary the tints, without causing any addition to the expense.

To prepare fine printed varnished cloths.—The process just described for manufacturing common varnished and polished cloths, may serve to give some idea of that employed for making fine cloths of the same kind, decorated with a coloured impression. The manufactories of Germany have varnished cloths embellished with large and small subjects, figures, and landscapes, well executed, and which are destined for covering furniture subjected to daily use.

This process, which is only an improvement of the former, requires a finer paste, and cloth of a more delicate texture. The stratum of paste is applied in the same manner, and when dry and polished, the cloth is taken from the frame and removed to the painter's table, where the art of the colourist and designer is displayed under a thousand forms; and, as in that of printed cottons, exhibits a richness of tints, and a distribution of subjects, which discover taste, and ensure a ready sale for the articles manufactured.

The process, however, employed in these two arts to extract the

colouring parts are not the same. In the art of cotton printing the colours are extracted by the bath, as in that of dyeing. In printing varnished cloths, the colouring parts are the result of the union of drying oil mixed with varnish, and the different colours employed in oil painting or painting in varnish.

The varnish applied to common oil cloth is composed of gum lac and drying linseed-oil; but that destined for printed varnished cloths requires some choice, both in regard to the oil and the resinous matter which gives it consistence. Prepared oil of pinks and copal form a varnish very little coloured, pliable, and solid.

To prepare varnished silk. No. 1.—Varnished silk, for making umbrellas, capots, coverings for hats, &c. is prepared in the same manner as the varnished and polished cloths already described, but with some variation in the liquid paste or varnish.

If the surface of the silk be pretty large, it is made fast to a wooden frame furnished with hooks and movable pegs, such as that used in the manufacture of common varnished cloths. A soft paste, composed of linseed-oil, boiled with a fourth part of litharge; tobacco-pipe clay, dried and sifted through a silk sieve, 16 parts; litharge ground on porphyry with water, dried and sifted in the same manner, 3 parts; and lamp-black, 1 part. This paste is then spread in an uniform manner over the surface of the silk, by means of a long knife, having a handle at each extremity. In summer, twenty-four hours are sufficient for its desiccation. When dry, the knots produced by the inequalities of the silk are smoothed with pumice-stone. This operation is performed with water, and when finished, the surface of the silk is washed. It is then suffered to dry, and flat copal varnish is applied.

If it be intended to polish this varnish, apply a second stratum; after which polish it with a ball of cloth and very fine tripoli. The varnished silk thus made is very black, exceedingly pliable, and has a fine polish. It may be rumpled a thousand ways without retaining any fold, or even the mark of one. It is light, and thereby proper for coverings to hats, and for making cloaks and caps so useful to travellers in wet weather.

No. 2.—A kind of varnished silk, which has only a yellowish colour, and which suffers the texture of the stuff to appear, is prepared with a mixture of 3 parts boiled oil of pinks, and 1 part of fat copal varnish, which is extended with a coarse brush or a knife. Two strata are sufficient when oil has been freed from its greasy particles over a slow fire, or when boiled with a fourth part of its weight of litharge.

The inequalities are removed by pumice-stone and water; after which the copal varnish is applied. This simple operation gives to white silk a yellow colour, which arises from the boiled oil and the varnish.

This varnished silk possesses all those qualities ascribed to certain preparations of silk which are recommended to be worn as jackets by persons subject to rheumatism.

To recover varnish.—Clear off the filth with a ley made of potash, and the ashes of the lees of wine; then take 48 ounces of potash, and 16 of the above-mentioned ashes, and put them into 6 quarts of water, and this completes the ley.

To polish varnish.—This is effected with pumice-stone and tripoli earth. The pumice-stone must be reduced to an impalpable powder, and put upon a piece of serge moistened with water; with this rub lightly and equally the varnished substance. The tripoli must also be reduced to a very fine powder, and put upon a clean woollen cloth, moistened with olive oil, with which the polishing is to be performed. The varnish is then to be wiped off with soft linen, and when quite dry, cleaned with starch or Spanish white, and rubbed with the palm of the hand.

ANTI-ATTRITION.

To prepare anti-attrition.—According to the specification of the patent, this mixture consists of one hundred weight of plumbago, to four hundred weight of hog's-lard, or other grease; the two to be well incorporated. The application is to prevent the effects of friction in all descriptions of engines or machines; and a sufficient quantity must be rubbed over the surface of the axle, spindle, or other part where the bearing is.

ASSAYING OF METALLIC ORES.

Before metallic ores are worked upon in the large way, it will be necessary to inquire what sort of metal, and what portion of it, is to be found in a determined quantity of the ore; to discover whether it will be worth while to extract it largely, and in what manner the process is to be conducted, so as to answer that purpose. The knowledge requisite for this, is called the art of assaying.

Assay of ores in the dry way.—The assaying of ores may be performed either in the dry or moist way; the first is the most ancient, and in many respects the most advantageous, and consequently still continues to be mostly used.

Assays are made either in crucibles with the blast of the bellows, or in tests under a muffle.

Assay weights.—The assay weights are always imaginary, sometimes an ounce represents an hundred weight on the large scale, and is subdivided into the same number of parts, as that hundred weight is in the great; so that the contents of the ore obtained by the assay shall accurately determine by such relative proportion, the quantity to be expected from any weight of the ore on a larger scale.

Roasting the ore.—In the lotting of the ores care should be taken to have small portions from different specimens, which should be pul-

verized, and well mixed in an iron or brass mortar. The proper quantity of the ore is now taken, and if it contain either sulphur or arsenic, it is put into a crucible or test, and exposed to a moderate degree of heat, till no vapour arises from it; to assist this volatilization, some add a small quantity of powdered charcoal.

Fluxes.—To assist the fusion of the ores, and to convert the extraneous matters connected with them into scoria, assayers use different kinds of fluxes. The most usual and efficacious materials for the composition of these are, borax, tartar, nitre, sal-ammoniac, common salt, glass, fluor-spar, charcoal powder, pitch, lime, litharge, &c. in different proportions.

Crude of white flux.—This consists of 1 part of nitre, and 2 of tartar well mixed together.

Black flux—The above crude flux detonates by means of kindled charcoal, and if the detonation be affected in a mortar slightly covered, the smoke that rises unites with the alkalised nitre and the tartar, and renders it black.

Cornish reducing flux.

10 oz. of tartar,
3 oz. and 6 drachms of nitre, and
3 oz. and 1 drachm of borax.—Mixt well together.

Cornish refining flux.—Deflagrate, and afterwards pulverize, 2 parts of nitre, and 1 part of tartar.

The above fluxes answer the purpose very well, provided the ores be deprived of all their sulphur; or, if they contain much earthly matters, because, in the latter case, they unite with them, and convert them into a thin glass: but if any quantity of sulphur remain, these fluxes unite with it, and form a liver of sulphur, which has the power of destroying a portion of all the metals; consequently, the assay under such circumstances must be very inaccurate. The principal difficulty in assaying appears to be in the appropriation of the proper fluxes to each particular ore, and it likewise appears, that such a discriminating knowledge can only be acquired from an extensive practice, or from a knowledge of the chemical affinities and actions of different bodies upon each other.

In assaying, we are at liberty to use the most expensive materials to effect our purpose, hence the use of different saline fluxes; but in the working at large, such expensive means cannot be applied; as by such processes, the inferior metals would be too much enhanced in value, especially in working very poor ores. In consequence of which, in smelting works, where the object is the production of metals in the great way, cheaper additions are used; such as limestone, feldt-spar, fluor-spar, quartz, sand, slate and slags. These are to be chosen according to the different views of the operator, and the nature of the ores. Thus iron ores, on account of the argillaceous earth they contain, require calcareous additions, and the copper ores, rather slags or vitrescent stones, than calcareous earth.

Humid assay of metallic ores.—The mode of assaying ores for their particular metals by the dry way, is deficient so far as relates to

pointing out the different substances connected with them, because they are always destroyed by the process for obtaining the assay metal. The assay by the moist way is more correct, because the different substances can be accurately ascertained. The late celebrated Bergman first communicated this method. It depends upon a knowledge of the chemical affinities of different bodies for each other; and must be varied according to the nature of the ore; it is very extensive in its application, and requires great patience and address in its execution. To describe the treatment of each variety of metallic ores, would take up too much of our room; but to give a general idea, we shall describe the procedure, both in the dry and the humid way, on one species of all the different ores.

To assay iron ores. No. 1.—The ore must be roasted till the vapour ceases to arise. Take 2 assay quintals of it, and triturate them with one of fluor-spar, $\frac{3}{4}$ of a quintal of powdered charcoal, and 4 quintals of decrepitated sea-salt; this mixture is to be put into a crucible, lined on the inside with clay and powdered charcoal; a cover must be luted upon the crucible, and the crucible itself exposed to a violent fire for an hour, and when it is cool, broken. When, if the operation has been well conducted, the iron will be found at the bottom of the crucible; to which must be added those metallic particles, which may adhere to the scoria. The metallic particles so adhering may be separated by pulverising it in paper, and then attracting them with a magnet.

No. 2.—If the ore should be in a calciform state, mixed with earths, the roasting of it previous to assaying, if not detrimental, is at least superfluous; if the earths should be of the argillaceous and siliceous kind, to half a quintal of them, add of dry quick-lime and fluor-spar of each 1 quintal and $\frac{1}{4}$, reduced to powder, and mix them with $\frac{1}{4}$ of a quintal of powdered charcoal, covering the whole with one ounce of decrepitated common salt; and expose the luted crucible to a strong forge-fire for an hour and a quarter, then let it gradually cool, and let the regulus be struck off and weighed.

No. 3.—If the ore contain calcareous earth, there will be no occasion to add quick-lime; the proportion of the ingredients may be as follows:—viz. 1 assay quintal of the ore; 1 of decrepitated sea-salt; $\frac{1}{2}$ of powdered charcoal; and 1 of fluor-spar, and the process conducted as above.

There is a great difference in the reguli of iron; when the cold regulus is struck with a hammer and breaks, the iron is called cold short: if it break on being struck red-hot, it is called red short; but if it resist the hammer, both in its cold and ignited state, it is good iron.

Humid assay of iron ore.—To assay the calciform ores, which do not contain much earthy or stony matter, they must be reduced to a fine powder, and dissolved in the marine acid, and precipitated by the Prussian alkali. A determinate quantity of the Prussian alkali must be tried previously, to acertain the portion of iron which it will precipitate, and the estimate made accordingly. If the iron

contain any considerable portion of zinc or manganese, the precipitate must be calcined to redness, and the calx treated with dephlogisticated nitrous acid, which will then take up only the calx of zinc; when this is separated, the calx should again be treated either with nitrous acid, with the addition of sugar, or with the acetous acid, which will dissolve the manganese, if any; the remaining calx of iron may then be dissolved by the marine acid, and precipitated by the mineral alkali; or it may be farther calcined, and then weighed.

Zinc ores.—Take the assay weight of roasted ore, and mix it well with ⅛ part of charcoal-dust, put it into a strong luted earthen retort, to which must be fitted a receiver; place the retort in a furnace, and raise the fire, and continue it in a violent heat for two hours, suffer it then to cool gradually, and the zinc will be found adhering to the neck of the retort in its metallic form.

In the humid way.—Distil vitriolic acid over calamine to dryness; the residuum must be lixiviated in hot water; what remains undissolved is siliceous earth; to the solution add caustic volatile alkali, which precipitates the iron and argil, but keeps the zinc in solution. The precipitate must be re-dissolved in vitriolic acid, and the iron and argil separated.

Tin ores.—Mix a quintal of tin ore, previously washed, pulverized, and roasted, till no arsenical vapour arises, with half a quintal of calcined borax, and the same quantity of pulverized pitch; these are to be put into a crucible moistened with charcoal-dust and water, and the crucible placed in an air-furnace. After the pitch is burnt, give a violent heat for a quarter of an hour, and on withdrawing the crucible, the regulus will be found at the bottom. If the ore be not well washed from earthy matters, a larger quantity of borax will be requisite, with some powdered glass; and if the ore contain iron, some alkaline salt may be added.

In the humid way.—The assay of tin ores in the liquid way, was looked upon as impracticable, till Bergman devised the following method, which is generally successful. Let the tin ore be well separated from its stony matrix, by well washing, and then reduced to the most subtle powder; digest it in concentrated oil of vitriol, in a strong heat for several hours, then, when cooled, add a small portion of concentrated marine acid, and suffer it to stand for an hour or two; then add water, and when the solution is clear, pour it off, and precipitate it by fixed alkali—131 grains of this precipitate, well washed and dried, are equivalent to 100 of tin in its reguline state, if the precipitate consists of pure tin; but if it contain copper or iron, it must be calcined in a red heat for an hour, and then digested in nitrous acid; which will take up the copper; and afterwards in marine acid, which will separate the iron.

Lead ores.—As most of the lead ores contain either sulphur or arsenic, they require to be well roasted. Take a quintal of roasted ore, with the same quantity of calcined borax, half a quintal of fine powdered glass, a quarter of a quintal of pitch, and as much clean iron filings. Line the crucible with wetted charcoal-dust, and put

the mixture into the crucible, and place it before the bellows of a forge fire. When it is red hot, raise the fire for 15 or 20 minutes, then withdraw the crucible, and break it when cold.

In the humid way.—Dissolve the ore by boiling it in a dilute nitrous acid; the sulphur, insoluble stony parts, and calx of iron will remain. The iron may be separated by digestion, in the marine acid, and the sulphur by digestion, in caustic fixed alkali. The nitrous solution contains the lead and silver, which should be precipitated by the mineral fixed alkali, and the precipitate well washed in cold water, dried, and weighed. Digest it in caustic volatile alkali, which will take up the calx of silver, the residuum being again dried and weighed, gives the proportion of the calx of lead, 132 grains of which are equal to 100 of lead in its metallic state. The difference of weight of the precipitate before and after the application of the volatile alkali, gives the quantity of silver, 129 grains of which are equal to 100 of silver in its metallic state.

Copper ores.—Take an extract troy ounce of the ore, previously pulverized, and calcine it well; stir it all the time with an iron rod, without removing it from the crucible; after the calcination add an equal quantity of borax, half the quantity of fusible glass, one-fourth the quantity of pitch, and a little charcoal-dust; rub the inner surface of the crucible with a paste composed of charcoal-dust, a little fine powdered clay and water. Cover the mass with common salt, and put a lid on the crucible, which is to be placed in a furnace: the fire is to be raised gradually, till it burns briskly, and the crucible continued in it for half an hour, stirring the metal frequently with an iron rod, and when the scoria which adheres to the rod appears clear, then the crucible must be taken out, and suffered to cool; after which it must be broken, and the regulus separated and weighed; this is called black copper, to refine which, equal parts of common salt and nitre are to be well mixed together. The black copper is brought into fusion, and a tea-spoonful of the flux is thrown upon it, which is repeated three or four times, when the metal is poured into an ingot mould, and the button is found to be fine copper.

In the humid way.—Make a solution of vitreous copper ore, in 5 times its weight of concentrated vitriolic acid, and boil it to dryness; add as much water as will dissolve the vitriol thus formed; to this solution add a clean bar of iron which will precipitate the whole of the copper in its metallic form. If the solution be contaminated with iron, the copper must be re-dissolved in the same manner, and precipitated again. The sulphur may be separated by filtration.

Bismuth ores.—If the ore be mineralized by sulphur, or sulphur and iron, a previous roasting will be necessary. The strong ores require no roasting, but only to be reduced to a fine powder. Take the assay weight and mix it with half the quantity of calcined borax, and the same of pounded glass; line the crucible with charcoal; melt it as quickly as possible; and when well done, take out the cru-

cible and let it cool gradually. The regulus will be found at the bottom.

In the humid way.—Bismuth is easily soluble in nitrous acid or aqua-regia. Its solution is colourless, and is precipitable by the addition of pure water; 118 grains of the precipitate from nitrous acid well washed and dried, are equal to 100 of bismuth in its metallic form.

Antimonial ores.—Take a common crucible, bore a number of small holes in the bottom, and place it in another crucible a size smaller, luting them well together; then put the proper quantity of ore in small lumps into the upper crucible, and lute thereon a cover; place these vessels on a hearth, and surround them with stones about six inches distant from them; the intermediate space must be filled with ashes, so that the undermost crucible may be covered with them; but upon the upper charcoal must be laid, and the whole made red hot by the assistance of hand-bellows. The antimony being of easy fusion is separated, and runs through the holes of the upper vessel into the inferior one, where it is collected.

Humid assay of arseniated antimony.—Dissolve the ore in aqua-regia, both the regulus and arsenic remain in the solution, the sulphur is separated by filtration. If the solution be boiled with twice its weight of strong nitrous acid, the regulus of antimony will be precipitated and the arsenic converted into an acid, which may be obtained by evaporation to dryness.

Manganese ore.—The regulus is obtained by mixing the calx or ore of manganese with pitch, making it into a ball, and putting it into a crucible, lined with powdered-charcoal, 1-10th of an inch on the sides, and ¼ of an inch at bottom, then filling the empty space with chacoal-dust, covering the crucible with another inverted and luted on, and exposing it to the strongest heat of a forge for an hour or more.

In the humid way.—The ores should be first well roasted to dephlogisticate the calx of maganese and iron, if any, and then treated with nitrous acid to dissolve the earths. The residuum should now be treated with nitrous acid and sugar, by which means a colourless solution of manganese will be obtained, and likewise of the iron, if any. Precipitate with the Prussian alkali, and digest the precipitate in pure water; the prussiate of manganese will be dissolved, whilst the prussiate of iron will remain undissolved.

Arsenical ores.—This assay is made by sublimation in close vessels. Beat the ore into small pieces, and put them into a matrass, which place in a sand-pot, with a proper degree of heat; the arsenic sublimes in this operation, and adheres to the upper part of the vessel, when it must be carefully collected with a view to ascertain its weight. Sometimes a single sublimation will not be sufficient, for the arsenic in many cases will melt with the ore, and prevent its total volatilization; in which case it is better to perform the first sublimation with a moderate heat, and afterwards bruise the remainder again, and expose it to a stronger heat.

In the humid way.—Digest the ore in marine acid, adding the nitrous by degrees to help the solution. The sulphur will be found on the filter; the arsenic will remain in the solution, and may be precipitated in its metallic form by zinc, adding spirit of wine to the solution.

Nickel ore.—The ores must be well roasted to expel the sulphur and arsenic; the greener the calx proves during this torrefaction, the more it abounds in the nickel; but the redder it is, the more iron it contains. The proper quantity of this roasted ore is fused in an open crucible, with twice or thrice its weight of black flux, and the whole covered with common salt. By exposing the crucible to the strongest heat of a forge-fire, and making the fusion complete, a regulus will be produced. This regulus is not pure, but contains a portion of arsenic, cobalt, and iron. Of the first it may be deprived by a fresh calcination, with the addition of powdered charcoal; and of the second by scorification; but it is with difficulty that it is entirely freed from the iron.

In the humid way.—By solution in nitrous acid, it is freed from its sulphur; and by adding water to the solution, bismuth, if any, may be precipitated: as may silver, if contained in it, by the marine acid; and copper, when any, by iron.

To separate cobalt from nickel, when the cobalt is in considerable quantity, drop a saturated solution of the roasted ore in nitrous acid into liquid volatile alkali; the cobaltic part is instantly re-dissolved and assumes a garnet colour; when filtered, a grey powder remains on the filter, which is the nickel. The cobalt may be precipitated from the volatile alkali by any acid.

Cobalt ores.—Free them as much as possible from earthy matters by well washing, and from sulphur and arsenic by roasting. The ore thus prepared is to be mixed with three parts of black flux, and a little decrepitated sea-salt: put the mixture in a lined crucible, cover it, and place it in a forge-fire, or in a hot furnace, for this ore is very difficult of fusion.

When well fused, a metallic regulus will be found at the bottom, covered with a scoria of a deep blue colour: as almost all cobalt ores contain bismuth, this is reduced by the same operation as the regulus of cobalt: but as they are incapable of chemically uniting together, they are always found distinct from each other in the crucible. The regulus of bismuth having a greater specific gravity, is always at the bottom, and may be separated by a blow with a hammer.

In the humid way.—Make a solution of the ore in nitrous acid, or aqua-rega, and evaporate to dryness; the residuum, treated with the acetous acid will yield to it the cobaltic part; the arsenic should be first precipitated by the addition of water.

Mercurial ores.—The calciform ores of mercury are easily reduced without any addition. A quintal of the ore is put into a retort, and a receiver luted on, containing some water; the retort is placed in a sand-bath, and a sufficient degree of heat given it, to force over the mercury which is condensed in the water of the receiver.

Sulphurated mercurial ores.—The sulphureous ores are assayed by distillation in the manner above, only these ores require an equal weight of clean iron-filings to be mixed with them, to disengage the sulphur, while the heat volatilizes the mercury, and forces it into the receiver. These ores should likewise be tried for cinnabar, to know whether it will answer the purpose of extracting it from them: for this a determinate quantity of the ore is finely powdered and put into a glass vessel, which is exposed to a gentle heat at first, and gradually increased till nothing more is sublimed. By the quantity thus acquired a judgment may be formed whether the process will answer. Sometimes this cinnabar is not of so lively a colour as that which is used in trade; in this case it may be refined by a second sublimation, and if it be still of too dark a colour, it may be brightened by the addition of a quantity of mercury, and subliming it again.

Humid assay of cinnabar.—The stony matrix should be dissolved in nitrous acid, and the cinnabar, being disengaged, should be boiled in 8 or 10 times its weight of aqua-regia, composed of 3 parts nitrous, and 1 of marine acid. The mercury may be precipitated in its running form by zinc.

Silver ores.—Take the assay quantity of the ore finely powdered, and roast it well in a proper degree of heat, frequently stirring it with an iron rod; then add to it about double the quantity of gray granulated lead, put it in a covered crucible and place it in a furnace; raise the fire gently at first, and continue to increase it gradually, till the metal begins to work; if it should appear too thick, make it thinner by the addition of a little more lead; if the metal should boil too rapidly, the fire should be diminished. The surface will be covered by degrees with a mass of scoria, at which time the metal should be carefully stirred with an iron hook heated, especially towards the border, lest any of the ore should remain undissolved; and if what is adherent to the hook when raised from the crucible, melts quickly again, and the extremity of the hook, after it is grown cold, is covered with a thin, shining, smooth crust, the scorification is perfect; but, on the contrary, if while stirring it, any considerable clamminess is perceived in the scoria, and when it adheres to the hook, though red hot, and appears unequally tinged, and seems dusty or rough, with grains interspersed here and there, the scorification is incomplete, in consequence of which the fire should be increased a little, and what adheres to the hook should be gently beaten off, and returned with a small ladle into the crucible again. When the scorification is perfect, the metal should be poured into a cone, previously rubbed with a little tallow, and when it becomes cold, the scoria may be separated by a few strokes of a hammer. The button is the produce of the assay.

By cupellation.—Take the assay quantity of ore, roast and grind it with an equal portion of litharge, divide it into 2 or 3 parts, and wrap each up in a small piece of paper; put a cupel previously seasoned under a muffle, with about 6 times the quantity of lead upon it. When the lead begins to work, carefully put one of the papers upon

it, and after this is absorbed, put on a second, and so on till the whole quantity is introduced; then raise the fire, and as the scoria is formed, it will be taken up by the cupel, and at last the silver will remain alone. This will be the produce of the assay, unless the lead contains a small portion of silver, which may be discovered by putting an equal quantity of the same lead on another cupel, and working it off at the same time; if any silver be produced it must be deducted from the assay. This is called the witness.

In the humid way.—Boil vitreous silver ore in dilute nitrous acid, using about 25 times its weight, until the sulphur is quite exhausted. The silver may be precipitated from the solution by marine acid, or common salt; 100 grains of this precipitate contain 75 of real silver; if it contain any gold it will remain undissolved. Fixed alkalies precipitate the earthy matters, and the Prussian alkali will show if any other metal be contained in the solution.

To assay the value of silver.—The general method of examining the purity of silver is by mixing it with a quantity of lead proportionate to the supposed portion of alloy: by testing this mixture, and afterwards weighing the remaining button of silver. This is the same process as refining silver by cupellation.

It is supposed that the mass of silver to be examined, consists of 12 equal parts, called penny-weights; so that if an ingot weighs an ounce, each of the parts will be 1-12th of an ounce. Hence, if the mass of silver be pure, it is called silver of 12 penny-weights; if it contain 1-12th of its weight of alloy, it is called silver of 11 penny-weights: if 2-12ths of its weight be alloy, it is called silver of 10 penny-weights; which parts of pure silver are called 5 penny-weights. It must be observed here, that assayers give the name penny-weight to a weight equal to 24 real grains, which must not be confounded with their ideal weights. The assayers' grains are called fine grains. An ingot of fine silver, or silver of 12 penny-weights, contains, then, 288 fine grains; if this ingot contain 1-288th of alloy, it is said to be silver of 11 penny-weights and 23 grains; if it contain 4-288ths of alloy, it is said to be 11 penny-weights, 20 grains, &c. Now a certain real weight must be taken to represent the assay-weights: for instance, 36 real grains represent 12 fine penny-weights; this is subdivided into a sufficient number of other smaller weights, which also represent fractions of fine penny-weights and grains. Thus, 18 real grains represent 6 fine penny-weights; 3 real grains represent 1 fine penny-weight, or 24 grains; a real grain and a half represents 12 fine grains: 1-32d of a real grain represents a quarter of a fine grain, which is only 1-752nd part of a mass of 12 penny-weights.

Double assay of silver.—It is customary to make a double assay. The silver for the assay should be taken from opposite sides of the ingot, and tried on a touch-stone. Assayers know pretty nearly the value of silver merely by the look of the ingot, and still better by the test of the touchstone. The quantity of lead to be added is re-

gulated by the portion of alloy, which being in general copper, will be nearly as follows:

Silver of dwts.	*grs.*	*dwts.grs.*		*Requires from*	
11	6 —	— —		5 to 6	Times its weight of lead.
0	12 —	— —		8 — 9	
From 19	18 to	9	0	12 — 13	
8	6 —	7	12	13 — 14	
6	18 —	6	0	14 — 15	
3	0 —	1	12	0 — 16	
1	12 —	0	18	0 — 20	

The cupel must be heated red hot for half an hour before any metal is put upon it, by which all moisture is expelled. When the cupel is almost white by heat, the lead is put into it, and the fire increased till the lead becomes red hot, smoking, and agitated by a motion of all its parts, called its circulation. Then the silver is to be put on the cupel, and the fire continued till the silver has entered the lead; and when the mass circulates well, the heat must be diminished by closing more or less the door of the assay furnace. The heat should be so regulated, that the metal on its surface may appear convex and ardent, while the cupel is less red; that the smoke shall rise to the roof of the muffle; that undulations shall be made in all directions; and that the middle of the metal shall appear smooth, with a small circle of litharge, which is continually imbibed by the cupel. By this treatment, the lead and alloy will entirely be absorbed by the cupel, and the silver become bright and shining, when it is said to lighten; after which, if the operation has been well performed, the silver will be covered with rainbow colours, which quickly undulate and cross each other, and then the button becomes fixed and solid.

The diminution of weight shows the quantity of alloy. As all lead contains a small portion of silver, an equal weight with that used in the assay is tested off, and the product deducted from the assay weight. This portion is called the witness.

To assay plated metals.—Take a determinate quantity of the plated metal; put it into an earthen vessel, with a sufficient quantity of the above menstruum, and place it in a gentle heat. When the silver is stripped, it must be collected with common salt; the calx must be tested with lead, and the estimate made according to the product of silver.

Ores and earths containing gold.—No. 1.—That which is now most generally used is by amalgamation; the proper quantity is taken and reduced to a powder, about 1-10th of its weight of pure quicksilver is added, and the whole triturated in an iron mortar. The attraction subsisting between the gold and quicksilver quickly unites them in the form of an amalgam, which is pressed through shamois leather; the gold is easily separated from this amalgam, by exposure to a proper degree of heat, which evaporates the quicksilver and leaves the gold. This evaporation should be made with luted vessels.

This is the foundation of all the operations by which gold is obtained from the rich mines of Peru, in Spanish America.

No. 2.—Take a quantity of the gold-sand, and heat it red hot, quench it in water; repeat this two or three times, and the colour of the sand will become a reddish-brown. Then mix it with twice its weight of litharge, and revive the litharge into lead, by adding a small portion of charcoal-dust, and exposing it to a proper degree of heat; when the lead revives, it separates the gold from the sand; and the freeing of the gold from the lead must be afterwards performed by cupellation.

No. 3.—Bergman assayed metallic ores containing gold, by mixing two parts of the ore, well pounded and washed, with $1\frac{1}{2}$ of litharge and three of glass, covering the whole with common salt, and melting it in a smith's forge, in a covered crucible; he then opened the crucible, put a nail into it, and continued to do so, till the iron was no longer attacked. The lead was thus precipitated which contained the gold, and was afterwards separated by cupellation.

Humid assay of gold mixed with martial pyrites.—Dissolve the ore in twelve times its weight of dilute nitrous acid, gradually added; place it in a proper degree of heat; this takes up the soluble parts, and leaves the gold untouched, with the insoluble matrix, from which it may be separated by aqua-regia. The gold may be again separated from the aqua-regia by pouring ether upon it; the ether takes up the gold, and by being burnt off, leaves it in its metallic state. The solution may contain iron, copper, manganese, calcareous earth, or argil; if it be evaporated to dryness, and the residuum heated to redness for half an hour, volatile alkali will extract the copper; dephlogisticated nitrous acid, the earths; the acetous acid, the manganese; and the marine acid, the calx of iron. The sulphur floats on the first solution, from which it should be separated by filtration.

PARTING.

By this process gold and silver are separated from each other. These two metals equally resisting the action of fire and lead, must therefore be separated by other means. This is effected by different menstrua. Nitrous acid, marine acid and sulphur, which cannot attack gold, operate upon silver; and these are the principle agents employed in this process.

Parting by nitrous acid is most convenient, consequently most used,—indeed, it is the only one employed by goldsmiths. This is called simply parting.

That made by the marine acid is by cementation, and is called centrated parting; and parting by sulphur is made by fusion, and called Dry Parting.

Parting by aqua-fortis. This process cannot succeed unless we attend to some essential circumstances: 1st. The gold and silver must be in a proper portion, viz. the silver ought to be three parts to one of gold; though a mass containing two parts of silver to one

of gold may be parted. To judge of the quality of the metal to be parted, assayers make a comparison upon a touch-stone, between it and certain needles composed of gold and silver, in graduated proportions, and properly marked; which are called Proof Needles. If this trial shows that the silver is not to the gold as three to one, the mass is improper for the operation, unless more silver be added; and 2dly, that the parting may be exact, the aqua-fortis must be very pure, especially free from any mixture of the vitriolic or marine acid. For if this were not attended to, a quantity of silver proportionable to these two foreign acids would be separated during the solution; and this quantity of sulphate of silver would remain mingled with the gold, which consequently would not be entirely purified by the operation.

The gold and silver to be parted ought previously to be granulated, by melting it in a crucible, and pouring it into a vessel of water, giving the water at the same time a rapid circular motion, by quickly stirring it round with a stick. The vessels generally used in this operation are called parting glasses, which ought to be very well annealed, and chosen free from flaws; as one of the chief inconveniences attending the operation is, that the glasses are apt to crack by exposure to cold, or even when touched by the hand. Some operators secure the bottom of the glasses by a coating composed of a mixture of new-slaked lime, with beer and whites of eggs spread on a cloth, and wrapped round the glasses at the bottom, over which they apply a composition of clay and hair. The parting glasses should be placed in vessels containing water supported by trivets, with a fire under them; because if a glass should break, the contents are caught in the vessel of water. If the heat communicated to the water be too great, it may be properly regulated by pouring cold water gradually and carefully down the side of the vessel into a parting glass 15 inches high, and 10 or 12 inches wide at the bottom; placed in a copper pan 12 inches wide at bottom, 15 inches wide at top, and 10 inches high; there is usually put about 80 oz. of metal, with twice as much of aqua-fortis.

The aqua-fortis ought to be so strong as to act sensibly on silver when cold, but not so strong as to act violently. Little heat should be applied at first, as the liquor is apt to swell and rise over the vessel; but when the acid is nearly saturated, the heat may safely be increased. When the solution ceases, which is known by the effervescence discontinuing, the liquor is to be poured off; if any grains appear entire, more aqua-fortis must be added, till the silver is all dissolved. If the operation has been performed slowly, the remaining gold will have the form of distinct masses. The gold appears black after parting; its parts have no adhesion together, because the silver dissolved from it has left many interstices. To give them more solidity, and improve their colour, they are put into a test under a muffle, and made red hot, after which they contract and become more solid, and the gold resumes its colour and lustre. It is then called Grain Gold. If the operation has been performed hastily, the gold will

have the appearance of black mud or powder, which, after well washing, must be melted.

The silver is usually recovered by precipitating it from the aqua-fortis by means of pure copper. If the solution be perfectly saturated, no precipitation can take place, till a few drops of aqua-fortis are added to the liquor. The precipitate of silver must be well washed with boiling water, and may be fused with nitre, or tested off with lead.

Parting by cementation.—A cement is prepared, composed of 4 parts of bricks powdered and sifted; of one part of green vitriol calcined till it becomes red; and of one part of common salt: this is to be made into a firm paste with a little water. It is called the Cement Royal.

The gold to be cemented is reduced into plates as thin as money. At the bottom of the crucible or cementing pot, a stratum of cement, of the thickness of a finger, is put, which is covered with plates of gold; and so the strata are placed alternately. The whole is covered with a lid, which is luted with a mixture of clay and sand. This pot must be placed in a furnace or oven, heated gradually until it becomes red hot, in which it must be continued during 24 hours. The heat must not melt the gold. The pot or crucible is then suffered to cool; and the gold carefully separated from the cement, and boiled at different times in a large quantity of pure water. It is then assayed upon a touch-stone, or otherwise; and if it be not sufficiently pure, is is cemented a second time. In this process the vitriolic acid of the bricks, and of the calcined vitriol, decomposes the common salt during the cementation, by uniting to its alkaline base, while the marine acid becomes concentrated by the heat, and dissolves the silver alloyed with the gold. This is a very troublesome process, though it succeeds when the portion of silver is so small that it would be defended from the action of aqua-fortis by the superabundant gold; but is little used, except to extract silver, or base metals, from the surface of gold, and thus giving to an alloyed metal, the colour and appearance of pure gold.

Dry parting.—This process is performed by sulphur, which will easily unite with silver, but does not attack gold. As this dry parting is even troublesome as well as expensive, it ought not to be undertaken but on a considerable quantity of silver alloyed with gold. The general procedure is as follows.—The metal must be granulated; from 1-8 to 1-5 of it, (according as it is richer or poorer in the gold,) is reserved, and the rest well mingled with an eighth of powdered sulphur; and put into a crucible, keeping a gentle fire, that the silver, before melting, may be thoroughly penetrated by the sulphur; if the fire be hastily urged, the sulphur will be dissipated. If to sulphurated silver infusion, pure silver be added, the latter falls to the bottom, and forms there a distinct fluid, not miscible with the other. The particles of gold having no affinity with the sulphurated silver, join themselves to the pure silver wherever they come in contact, and are thus tranferred from the former into the latter, more or

less perfectly, according as the pure silver was more or less thoroughly diffused through the mixture. It is for this use that a part of the granulated silver was reserved. The sulphurated mass being brought into fusion, and kept melting for nearly an hour in a covered crucible, one third of the reserved grains is thrown in, which, when melted, the whole is well stirred, that the fresh silver may be distributed through the mixed to collect the gold from it; this is performed with a wooden rod. This is repeated till the whole reserved metal be introduced. The sulphurated silver appears, in fusion, of a dark brown colour; after it has been kept in fusion for a certain time, a part of the sulphur having escaped from the top, the surface becomes white, and some bright drops of silver, about the size of a pea, are perceived on it. When this happens the fire must be immediately discontinued, for otherwise more and more of the silver thus losing its sulphur, would subside and mingle with the part at the bottom, in which the gold is collected. The whole is poured into an iron mortar greased and duly heated. The gold diffused at first through the whole mass, is now found collected in a part of it at the bottom, (amounting only to about as much as was reserved unsulphurated from the mass,) by a chisel or hammer, or more perfectly by placing the whole mass with its bottom upwards in a crucible, the sulphurated part quickly melts, leaving, unmelted, that which contains the gold. The sulphurated silver is assayed, by keeping a portion of it in fusion in an open crucible, till the sulphur is dissipated, and then by dissolving it in aqua-fortis. If it should still be found to contain gold, it must be subjected to the same treatment as before. The gold thus collected may be concentrated into a smaller part by repeating the whole process, so that at last it may be parted by aqua-fortis without too much expense.

IRON AND STEEL.

Expeditious mode of reducing iron ore into malleable iron.—The way of proceeding is by stamping, washing, &c. the calcine and materials, to separate the ore from extraneous matter; then fusing the prepared ore in an open furnace, and instead of casting it, to suffer it to remain at the bottom of the furnace till it becomes cold.

New method of shingling and manufacturing iron.—The ore being fused in a reverberating furnace, is conveyed, whilst fluid, into an air-furnace, where it is exposed to a strong heat, till a bluish flame is observed on the surface; it is then agitated on the surface, till it loses its fusibility, and is collected into lumps called *loops.* These *loops* are then put into another air-furnace, brought to a white or welding heat, and then *shingled* into *half-blooms* or *slabes.* They are again exposed to the air-furnace, and the half-blooms taken out and forged into *anconies*, *bars*, *half-flats*, and *rods* for *wire;* while the *slabes* are passed, when of a welding heat, through the grooved rollers. In this way of proceeding, it matters not whether the iron is prepared from *cold* or *hot-short* metal, nor is there any occasion

for the use of finery, charcoal, coke, chafery, or hollow fire; or any blast by bellows, or otherwise: or the use of fluxes, in any part of the process.

Approved method of welding iron.—This consists in the skilful *bundling* of the iron to be welded; in the use of an extraordinary large forge-hammer, in employing a *balling-furnace*, instead of a *hollow fire* or *chafery;* and in passing the iron, reduced to a melting heat, through grooved mill-rollers of different shapes and sizes, as required.

Common hardening.—Iron, by being heated red hot, and plunged into cold water, acquires a great degree of hardness. This proceeds from the coldness of the water which contracts the particles of the iron into less space.

Case-hardening.—Case-hardening is a superficial conversion of iron into steel by cementation. It is performed on small pieces of iron, by enclosing them in an iron box, containing burnt leather, bone-dust, or any other carbonic material, and exposing them for some hours to a red heat. The surface of the iron thus becomes perfectly metalized. Iron thus treated is susceptible of the finest polish.

To convert iron into steel by cementation.—The iron is formed into bars of a convenient size, and then placed in a cementing furnace, with sufficient quantity of cement, which is composed of coals of animal or vegetable substances, mixed with calcined bones, &c. The following are very excellent cements:—1st, one part of powdered charcoal, and half a part of wood-ashes well mixed together; or, 2dly, two parts of charcoal, moderately powdered, one part of bones, horn, hair, or skins of animals, burnt in close vessels to blackness and powdered; and half a part of wood ashes; mix them well together. The bars of iron to be converted into steel, are placed upon a stratum of cement, and covered all over with the same; and the vessel which contains them, closely luted, must be exposed to a red heat for 8 or 10 hours, when the iron will be converted into steel.

Steel is prepared from bar-iron by fusion; which consists of plunging a bar into melted iron, and keeping it there for some time, by which process it is converted into good steel.

All iron which becomes harder by suddenly quenching in cold water is called steel; and that steel which in quenching acquires the greatest degree of hardness in the lowest degree of heat, and retains the greatest strength in and after induration, ought to be considered as the best.

Improved process of hardening steel.—Articles manufactured of steel for the purposes of cutting, are, almost without an exception, hardened from the anvil; in other words, they are taken from the forger to the hardener without undergoing any intermediate process: and such is the accustomed routine, that the mischief arising has escaped observation. The act of forging produces a strong scale or coating, which is spread over the whole of the blade; and to make the evil still more formidable, this scale or coating is unequal in substance, varying in proportion to the degree of heat communicated to the steel in forging; it is, partially, almost impenetrable to the

action of water when immersed for the purpose of hardening. Hence it is that different degrees of hardness prevail in nearly every razor manufactured: this is evidently a positive defect; and so long as it continues to exist, great difference of temperature must exist likewise. Razor-blades not unfrequently exhibit the fact here stated in a very striking manner; what are termed clouds, or parts of unequal polish, derive their origin from this cause; and clearly and distinctly, or rather *distinctly* though not *clearly*, show how far this partial coating has extended, and where the action of the water has been yielded to, and where resisted. It certainly cannot be a matter of astonishment that so few improvements have been made in the hardening of steel, when the evil here complained of so universally obtains, as almost to warrant the supposition that no attempt has ever been made to remove it. The remedy, however, is easy and simple in the extreme, and so evidently efficient in its application, that it cannot but excite surprise, that, in the present highly improved state of our manufactures, such a communication should be made as a discovery entirely new.

Instead, therefore, of the customary mode of hardening the blade from the anvil, let it be passed immediately from the hands of the forger to the grinder; a slight application of the stone will remove the whole of the scale or coating, and the razor will then be properly prepared to undergo the operation of hardening with advantage. It will be easily ascertained, that steel in this state heats in the fire with greater regularity, and that when immersed, the obstacles being removed to the immediate action of the water on the body of the steel, the latter becomes equally hard from one extremity to the other. To this may be added, that, as *the lowest possible heat at which steel becomes hard is indubitably the best*, the mode here recommended will be found the only one by which the process of hardening can be effected with a less portion of fire than is, or can be required in any other way. These observations are decisive, and will, in all probability, tend to establish in general use what cannot but be regarded as a very important improvement in the manufacturing of edged steel instruments.

English cast steel.—The finest kind of steel, called *English cast steel*, is prepared by breaking to pieces blistered steel, and then melting it in a crucible with a flux composed of carbonaceous and vitrifiable ingredients. The vitrifiable ingredient is used only inasmuch as a fusible body, which flows over the surface of the metal in the crucibles, and prevents the access of the oxygen of the atmosphere. Broken glass is sometimes used for this purpose.

When thoroughly fused it is cast into ingots, which by gentle heating and careful hammering, are tilted into bars. By this process the steel becomes more highly carbonized in proportion to the quantity of flux, and in consequence is more brittle and fusible than before. Hence, it surpasses all other steel in uniformity of texture, hardness, and closeness of grain, and is the material employed in all the finest articles of English cutlery.

To make edge-tools from cast steel and iron.—This method consists in fixing a clean piece of wrought iron, brought to a welding heat, in the centre of a mould, and then pouring in melted steel, so as entirely to envelope the iron; and then forging the mass into the shape required.

To colour steel blue.—The steel must be finely polished on its surface, and then exposed to an uniform degree of heat. Accordingly, there are three ways of colouring: first, by a flame producing no soot, as spirit of wine; secondly, by a hot plate or iron; and thirdly, by wood ashes. As a very regular degree of heat is necessary, wood-ashes for fine work bears the preference. The work must be covered over with them, and carefully watched; when the colour is sufficiently heightened, the work is perfect. This colour is occasionally taken off with a very dilute marine acid.

To distinguish steel from iron.—The principal characters by which steel may be distinguished from iron, are as follow:

1. After being polished, steel appears of a whiter, light grey hue, without the blue cast exhibited by iron. It also takes a higher polish.

2. The hardest steel, when not annealed, appears granulated, but dull, and without shining fibres.

3. When steeped in acids, the harder the steel is, of a darker hue is its surface.

4. Steel is not so much inclined to rust as iron.

5. In general, steel has a greater specific gravity.

6. By being hardened and wrought, it may be rendered much more elastic than iron.

7. It is not attracted so strongly by the magnet as soft iron. It likewise acquires magnetic properties more slowly, but retains them longer; for which reason, steel is used in making needles for compasses, and artificial magnets.

8. Steel is ignited sooner, and fuses with less degree of heat than malleable iron, which can scarcely be made to fuse without the addition of powdered charcoal; by which it is converted into steel, and afterwards into crude iron.

9. Polished steel is sooner tinged by heat, and that with higher colours, than iron.

10. In a calcining heat, it suffers less loss by burning, than soft iron does in the same heat, and the same time. In calcination a light blue flame hovers over the steel, either with or without a sulphureous odour.

11. The scales of steel are harder and sharper than those of iron; and consequently more fit for polishing with.

12. In a white heat, when exposed to the blast of the bellows among the coals, it begins to sweat, wet, or melt, partly with light-coloured and bright, and partly with red sparkles, but less crackling than those of iron. In a melting heat too, it consumes faster.

13. In the vitriolic, nitrous and other acids, steel is violently attacked, but is longer in dissolving than iron. After maceration, according as it is softer or harder, it appears of a lighter, or darker grey colour; while iron on the other hand is white.

GLOSSARY.

Æolopile - -	A hollow metallic ball, with a small orifice, to show the power of steam.
Anneal - - -	To expose iron or other metals to the action of fire, in order to reduce them to a greater degree of tenacity.
Anvil - - -	A block or mass of iron, with a hardened steel surface, on which smiths and other artificers hammer and fashion their work.
Arbor - - -	The principal spindle or axis which communicates motion to the other parts of a machine.
Arm - - -	The length of the sail of a windmill measured from the axis.
Arms (*axle*) - -	The two ends of an axle-tree: projecting supports in machinery.
Ash-hole - - -	A receptacle for the ashes which fall from the hearth of a furnace.
Attraction of cohesion	The attraction which holds the particles of matter to each other.
——— *of gravitation*	The force which causes all ponderous bodies to fall towards the earth's centre.
Augur - - -	The wimble or tool used in the boring of woods.
Automaton - -	A machine which, by an internal arrangement, seems to move of itself.
Axis - - -	The spindle or centre of any rotatory motion.
—— *of oscillation* -	The shaft upon which any body vibrates.
—— *in peritrochio* -	One of the six mechanical powers; usually called the wheel and axle.
—— *of rotation* -	The shaft round which any body revolves.
Backboards - -	Boards attached to the rims of the water-wheel, to prevent the water running off the floats into the interior of the wheel.
Backlash - -	The hobbling movement of a wheel not fixed firm on its axis.
Back-water - -	The water which impedes the motion of a water-wheel during floods, or from other causes.
Balance - - -	An instrument which, by the application of the lever, exhibits the weights of bodies.

Batten - - -	The movable lath or bar of a loom which serves to strike in or close, more or less, the threads of a woof: a long narrow slip of wood in carpentry
Batter - - -	A machine used early in the process of the cotton manufacture.
Bayonet - - -	A piece of wood or metal with two legs to disengage and re-engage machinery: *vide* Mill-Geering.
Beats - - -	The strokes made by the pallets or fangs of a spindle in clock or watch movements.
Beetle - - -	An implement for flattening the texture of linen or woollen cloth: a heavy mallet.
Bevel-geer - -	Wheels in which the teeth are set at angles of various degrees from the radius.
Bitts - - -	Small tools used in boring.
Bloom - - -	A bar of iron to be passed through the rollers of an iron-mill to be elongated into a bar, rod, or hoop.
Blunging - -	The act of mixing or kneading clay for the potter's use.
Bobbins - - -	Little circular pieces of wood on which the thread of cotton, silk, &c. is wound.
Bolter - - -	A machine for sifting meal.
Bolting-cloth - -	A cloth through which the sifted meal runs.
Brace - - -	A curved instrument of iron or wood for moving small boring tools called bitts.
Bracket - - -	A support fixed to a wall.
Brake - - -	A machine for separating the cuticle or outer skin from the flax plant.
Brazing - - -	The soldering or joining two pieces of metal by melting of brass between the pieces to be joined.
Breast - - -	The first part of a revolver carding-engine.
Breasting - -	The circular sweep of masonry, &c. which surrounds the shuttle side of a breast-wheel.
Breast-plate - -	A small piece of steel with holes to receive the ends of a drill.
Breast-wheel - -	A water-wheel on which water is admitted at or nearly level with the axis.
Buff-stick - -	A piece of wood covered with buff leather, used for polishing.
Bullet - - -	To alter the wards of a lock in such manner that they may be passable by more than one key.
Bush - - -	A hole in the nave of a wheel.
Cæteris paribus -	Other things being equal.
Calibre - - -	The diameter of a hole.
Calk - - -	To force oakum, tow, or other material in

	the joints of vessels, to make them steam, air, or water-tight.
Camb - - -	An eccentric.
Capstan - - -	A vertical post resting on a pivot and turned by powerful arms or levers to raise heavy weights by crane work; a windlass.
Carbon - - -	Charcoal.
Card - - -	Piece of leather containing numerous iron-wire teeth, forming a species of comb; *vide* Cotton Manufacture.
Case-harden - -	The process of converting the surface of iron into steel.
Casting	The act of forming metal or other matter into any required shape, by pouring it into moulds while in a fluid state.
Catch - - -	Various contrivances in mechanics, to act on the principle of a latch.
Cement - - -	A composition for joining hard bodies.
Centre-bit - -	A boring tool in carpentry.
Centrifugal - -	Flying from the centre.
Centripetal - -	Flying to the centre.
Chafery - - -	A kind of forge in the iron manufacture, where the metal is exposed to a welding heat.
Chaliometer - -	An instrument to measure heat.
Chamfer - -	A groove to receive the tenon in carpentry.
Checks - - -	A term generally applied to those pieces of timber in machinery, which are double, and correspond with each other.
Chord - - -	Perpendicular let fall from any radius of a circle.
Chuck - - -	That part of a lath which revolves with the arbor: to this is affixed the article to be turned.
Circumference - -	The measure round any circle.
Clack - - -	A bell so contrived that it shall ring when more corn is required to be put in the mill.
Clamp - - -	A pile of unburnt bricks raised for burning.
Clip - - -	An arrangement to impede velocity by friction.
Clutch - - -	*Vide* Bayonet.
Cockling - - -	To entangle.
Cocoon - - -	A small ball of silk spun by a silk-worm.
Cog - - -	This word, correctly speaking, implies teeth formed of a different material to the body of the wheel; but is generally used to express all kinds of toothed wheels.
Concentric - -	Having the same centre.
Conspiring forces -	Various forces combined into one.
Constant forces -	Force without interruption.

Contractile forces -	Forces which decrease.
Core - - -	The internal mould which forms a hollow in foundry: as the hollow of a tub or pipe.
Countersink - -	To take off the edge round a hole to let in a screw-head, that it may be even with the surface.
Couplings - -	To connect two shafts or spindles longitudinally.
Coupling-box - -	A strong piece of hollow iron to connect shafting and throw machinery in and out of geer.
Crank - - -	A bent part of a shaft, by means of which a rectilinear motion is gained.
Crow-bar - -	A strong bar of iron used as a temporary lever.
Crown-wheel - -	A wheel which has teeth at right angles to its radii.
Cycloid - - -	A geometric curve.
Cylinder - - -	A long round body; a roller.
Dam - - -	The bank or wall which pens back the water in a mill-head.
Data - - -	Facts from which we may deduce results.
Decimeter - -	To measure by tenths.
Dent - - -	The wire staple which constitutes the tooth of a card.
Devil - - -	A machine for dividing rags or cotton in the first process of the manufacture of paper or cotton.
Diameter - - -	The line which passes through the centre of a circle.
Die - - -	Pieces of steel for cutting screws, having the threads countersunk on them: a stamp.
Doffer - - -	That part of a carding machine which takes the cotton from the cylinder.
Doffing-plate - -	The plate which receives the cotton from the doffer.
Dog - - -	A piece in small machinery which acts as a pall.
Draw-plate - -	A steel plate, having a gradation of conical holes, through which metals are drawn to be reduced and elongated.
Drench - - -	To wet or inundate.
Drill-bow - -	A small bow moved by hand to impart motion to a drill.
Drum - - -	A hollow cylinder.
Ductile - - -	Malleable and soft.
Eccentric - -	Deviating from the centre; as cambs, attached to the rim or circumference of a shaft for lifting forge hammers, stampers, &c.

Effective-head - - The real head, or that which can be applied to practice.

Effluent - - - Flowing from; running out.

Efflux - - - The act of flowing out.

Epicycloid - - The curve described in the air by a point on the circumference of a circle, when this circle rolls on another circle as its base.

Equilibrium - . That peculiar state of rest in which a body is maintained by the force of gravitation, when the quantity of matter in it is exactly equal on each side of the bar or point on which it is supported.

Escapement - - The part of a clock or watch movement which receives the force of the spring or weight to give motion to the pendulum or balance.

Face of the tooth - The curved part of a tooth which imparts impulse to another wheel.

Faggot - - - Pieces of iron bound together for re-manufacture.

Fan - - - Small vanes or sails to receive the impulse of the wind, and, by a connexion with machinery, to keep the large sails of a smock wind-mill always in the direction of the wind: an instrument to winnow corn; also to decrease speed by its action on the air.

Female-screw - - The spiral threaded cavity in which a screw operates.

File - - - A tool used by smiths for the abrasion of metals; denominated, according to its fineness, rough, bastard, or smooth.

First-mover - - Power, either natural or artificial.

Flanch - - - An edge or projection for the better connexion of piping or castings of any description.

Flank of the tooth - The straight part of a tooth which receives impulse from another wheel.

Float - - - The board which receives the impulse of the water either in breast or undershot-wheels.

Floodgate - - A strong framing of timber to pen back or let out water.

Flux - - - Ingredients put into a smelting furnace to fuse the ore of metals.

Fly-wheel - - A heavy wheel to maintain equable motion.

Foot-brake - - A machine used in the flax manufacture.

Forge - - - A manufactory in which metals are made malleable; a furnace.

Forge - - - To form by the hammer.

Friction - - - Inequality of surface; act of rubbing together.

Frisket - - -	An iron frame used in printing to keep the sheet of paper on the tympan, and to prevent the margin from being blackened.
Fulcrum - -	The point or bar on which a lever rests.
Geering - -	Part of mill-work.
Gibbet - - -	That part of a crane which sustains the weight of goods.
Gig-mill - -	A mill in which the nap of woollen cloth is raised by the application of teasels.
Girder - - -	The largest timber in a floor.
Girt - - -	*Vide* Gripe.
Gravity - -	Tendency towards the centre of the earth: weight.
Gripe - - -	A pliable lever which can be pressed against a wheel to retard or stop its motion by friction.
Governor - -	A pair of heavy balls connected with machinery to regulate the speed on the principle of central force.
Gudgeon - -	The centres or pivots of a water-wheel.
Half-stuff - -	This term, in general, implies any thing half-formed in the process of the manufacture.
Heald or Heddle -	*Vide* Heddle.
Heckle - - -	A metal comb for the manufacture of flax.
Heddle - - -	That portion of a loom which imparts motion to the warp of a web during the process of manufacture.
Helve - - -	The shaft of a forge or tilt-hammer.
Hopper - - -	A funnel in which grain is deposited, whence it runs between the stones of a flour-mill.
Horology - -	The art of constructing machines for measuring time.
Hydraulics - -	The science which treats of the motion of fluids, of the resistance which they oppose to moving bodies, and of the various machines in which fluids are the principal agent.
Hydrodynamics -	The science which embraces the phenomena exhibited by water and other fluids, whether they be at rest or in motion: it is generally divided into two heads, hydrostatics and hydraulics.
Hydrostatics -	The science which considers the pressure, equilibrium, and cohesion of fluids.
Impact - - -	Transmission of force.
Impinge - -	To dash against.
Inertia - - -	That tendency which every piece of matter

has, when at rest, to remain at rest; and when in motion, to continue that motion.

In vacuo - - Empty space, void.

Isochronal - - Of equal duration.

Isochronous - - The vibrations of a pendulum.

Jenney. - - A machine used in the process of the cotton manufacture.

Jib - - - *Vide* Gibbet.

Kiln - - - A place where bricks are burnt.

Kink or Kinkle - The entangling of cordage from overtwisting.

Lateral - - - A horizontal or lengthwise movement.

Lathe - - - Machine used by turners.

Lantern - - A wheel with staff-teeth; the trundle or wallower.

Leaves - - - The teeth of a pinion.

Lever - - - One of the mechanical powers.

Line of centres - A line drawn from the centre of one wheel to the centre of another, when their circumferences touch each other.

Locomotive - - The power of changing place.

Loom - - - A machine used by weavers in the making of cloth.

Machinist - - One who makes machines.

Mandrel - - Part of a lathe; Cone used by smiths; a cylindrical piece of polished iron or steel put down the core or hole of a pipe during the process of elongation.

Mastering - - Preparation of lime used by tanners.

Matrice - - - The concave form of a letter in which the types are cast.

Maximum - - Is the utmost extent of any movement or power.

Mechanist - - One acquainted with the laws of mechanics.

Mill-head - - The head of water which is to turn a mill.

Mill-tail - - The water which has passed through the wheel-race, or is below the mill.

Minimum - - The reverse of maximum.

Momentum - - The force possessed by matter in motion.

Monkey - - - A weight or mass of iron let fall from a height to drive piles into the earth.

Mortise - - - A joint.

Movement - - The working part of a watch or clock.

Nave - - - The centre, or that part of a wheel in which the spokes or arms are fixed.

Nealing - - - *Vide* Annealing.

Nippers - - - Pincers with cutting edges for dividing metals.

Nitric acid - - A corrosive acid extacted from nitre.

Ouse - - - Preparation of bark used by tanners.

Overshot-wheel -	A wheel which receives the water in buckets at not more than 45 degrees from the apex.
Oxyd - - -	A combination of oxygen with a metallic or other base.
Oxygen - - -	A gas which supports combustion.
Paddle - - -	A kind of oar; floats to a wheel.
Pall - - -	A small piece of metal which falls between the teeth of a ratchet-wheel, to prevent a load which has been raised from descending when the operative power is removed.
Pallet - - -	That part of a watch or clock escapement on which the crown-wheel strikes.
Pendulum - -	A weight suspended by a flexible cord to an axis, so as to swing backwards and forwards, when once raised, by the force of gravitation.
Periphery - -	The circumference of a wheel.
Perpendicular - -	At right angles to a given base.
Pick - - -	A chisel for dressing the stones of a flour-mill.
Pile - - -	A large piece of timber, pointed at one end, to drive into the earth to sustain the piers of bridges, &c.
Pin - - -	To strike a piece of metal with the narrow end of a hammer to form dents and produce elongation.
Pincers - - -	A tool formed by placing two levers on one fulcrum, regulated by a screw-movement, for holding bodies firmly.
Pinion - - -	A small toothed wheel.
Pirn - - -	The wound yarn that is on a weaver's shuttle.
Piston - - -	A plug made to fit tight and work up and down a cylinder in hydraulic engines.
Pitch-lines - -	The touching circumferences of two wheels which are to act on each other.
Pitch of the wheel -	The distance from the centres of two teeth, measured upon their pitch line.
Pivot - - -	A short shaft on which a body turns or vibrates.
Platina - - -	A white metal capable of withstanding great heats.
Pliers - - -	A small tool constructed similarly to pincers.
Plumb - - -	A leaden weight suspended by a cord to ascertain the perpendicular.
Plunger - - -	A body that is forced into a fluid in hydraulic engines, to displace its own weight.
Portable steam-engine	A steam engine built in a compact form,

	and not attached to the wall of the building in which it works.
Proportional circles -	*Vide* Pitch-lines.
Proportional radii -	The radii of two circles whose circumferences are in contact.
Puddling - -	The act of ramming with clay to arrest the progress of water.
Puddling-furnace -	A furnace used in the iron manufactures.
Pulley - - -	A small wheel over which a strap is passed.
Quintal - - -	A French or Spanish weight equivalent to 100 lbs. of those respective nations.
Rabbit or Rap-it -	The strong wooden spring against which the forge hammer strikes on its ascent.
Race - - -	The canal along which the water is conveyed to and from a water-wheel.
Rack - - -	A straight bar which has teeth similar to those on a toothed wheel.
Radii - - -	The plural of radius.
Radius - - -	The semi-diameter of a circle; the arm or spoke of a wheel.
Rasp - - -	A species of file, on which the cutting prominences are distinct, being raised by a point instead of an edge.
Rasure - - -	The act of scraping.
Ratch - - -	A bar containing teeth into which the pall drops to prevent machines running back.
Ratchet-wheel - -	A wheel having teeth similar to those of a ratch.
Reciprocating - -	Acting alternately.
Rectilinear or rectilineal	Consisting of right lines.
Reed - - -	Part of a loom resembling a comb for dividing the warp.
Regulator - -	A small lever in watch-work, which, by being moved, increases or decreases the amount of the balance spring that is allowed to act.
Reel - - -	A frame on which yarn may be wound.
Reeling - - -	The act of winding yarn on a reel.
Resolution of forces	*Vide* "Of the Action of Forces," page 5.
Reservoir - -	A large basin or conservatory of water.
Reverberatory - -	Beating back.
Reverberatory-furnace	A furnace used in the iron and copper manufactures.
Rivet - - -	To form a head by the percussion of a hammer, to prevent a piece of metal which has been passed through an orifice, to connect things together, from returning.
Roller-gin - -	A machine to divest cotton of the husk and

	other superfluous parts, previous to the commencement of the manufacture.
Rotatory - -	Revolving.
Rowans - -	Cotton in that part of the manufacture before it goes to the roving frame.
Rubber - -	A heavy file used for coarse work.
Rubble - -	A mode of building; *vide* Masonry, p. 98, vol. ii.
Rynd - -	The piece of iron that goes across the hole in an upper mill-stone.
Safety-valve - -	A valve which fits on the boiler of a steam-engine to guard against accidents by the steam obtaining too high a pressure.
Saw-gin - -	A machine on the principle of the roller-gin.
Scantling - -	The length, breadth, and thickness of any solid body taken lineally.
Scapement - -	*Vide* Escapement.
Scotching - -	The operation of packing hemp before it goes to the market.
Scoria - - -	Slag from a smelting furnace.
Scowering barrel -	An octagonal, or other shaped barrel, in which scrap-iron, &c. is cleansed from rust by friction as it revolves.
Scrap-iron - -	Various pieces of old iron to be re-manufactured.
Screw - - -	One of the mechanical powers.
Scribbler-engine -	An engine used in the process of the cotton manufacture.
Shaft - - -	A long piece of wood or metal, on which large wheels are fixed in mill-work.
Sheeve - - -	A small kind of pulley.
Shoulder - -	A support by means of a projection from a surface.
Shrouding - -	The boards, &c. which form buckets of water-wheels.
Shuttle - -	An arrangement to allow or shut off water from a water-wheel; a small piece of wood which carries the thread in weaving.
Size - - -	Gelatinous matter made from animal or vegetable substances, and applied to fibrous materials to impart stiffness.
Slag - - -	Scoria, or refuse from an iron furnace.
Sledge-hammer -	A heavy hammer, used by a smith with both hands.
Slip - - -	Potter's clay of the requisite consistency.
Sluice - - -	Vent for water; a kind of flood-gate.
Snail movement -	An eccentric.
Solder - - -	Various compounds of metals for conjoining other metals that are less fusible than such compound.

Sparables - -	From sparrow-bill, small nails to drive into shoes.
Spatula - -	A thin knife, used mostly to extend superficially some semi-fluid matter.
Spindle - -	A thin piece of wood or steel on which yarn is wound after it has been twisted: a small kind of shaft.
Spokes - -	The radial pieces which connect the periphery of a wheel with its centre-piece or nave: this term is only applied to carriages.
Spring - -	An elastic body formed of metal or wood.
Spring-arbor - -	The arbor or spring round which the main spring of a watch is wound.
Spring-box - -	The box which contains the main spring.
Spur-geer - -	Wheels whose axes are parallel to each other.
Splice - - -	To conjoin lengthwise two flexible pieces: by the interposition of their respective parts, so as to maintain them in conjunction by friction.
Staff - - -	The teeth of a trundle, lantern, or wallower.
Staking-on - -	To drive wedges in the bush of a wheel or pulley, to fix it firm on a shaft or spindle.
Start or Strut -	The partitions which determine the form of a bucket in an over-shot wheel; the shoulder or wrest.
Staves - - -	The plural of staff.
Steam-boat - -	A boat moved by steam power.
Steam-engine - -	A machine for applying the force of steam to create motion.
Steel-yard - -	A machine which denotes the weight of bodies by placing them at different distances from its fulcrum.
Stereotype - -	The art of casting solid plates from movable types, to print from.
Strike - - -	A thing used to strike any thing level in a measure: the strickle.
Strata - - -	The plural of stratum.
Stratum - -	A single layer or bed of any one thing.
Stuff - - -	This term is applied to an infinite variety of things; wood is, by the carpenter, called stuff, so is lime and hair by the bricklayer, and plaster by the plasterer, &c.
Swag - - -	An unequal or hobbling motion.
Swifts - - -	The rapid movement in a carding machine.
Swingling - -	*Vide* Scotching.
Swing-tree - -	Any beam that vibrates.
Swivel - - -	A thing fixed in another body to turn round upon.

Syphon - - -	A bent tube with unequal legs through which a fluid will flow by the force of gravity.
Tail-water - -	Water which impedes the water-wheel in mill work.
Tank - - -	Reservoir for water, &c.
Teasels - -	Thistles used to raise the nap of cloth in the gig-mill.
Tenon - - -	That part which fills up the mortise.
Tilt-hammer - -	A hammer lifted by machinery, to force iron or steel.
Treadle - -	A lever affixed to a crank which communicates motion to machinery by a foot movement.
Throwsting - -	Spinning.
Triblet - -	*Vide* Mandrel.
Truckles - -	Small rollers for diminishing friction.
Trundle - -	A small wheel with staff teeth; the lantern or wallower.
Tuyere or Tue-iron	An orifice through which a blast or strong current of air is passed into forges.
Tympan - -	That part of a printing-press on which the paper is laid to receive the impression.
Undershot-wheel -	A wheel acted on by water below its centre.
Vacuum - -	Void of air.
Valve - - -	A cover to an aperture, in hydraulic machines, to prevent fluids taking a wrong course.
Vane - - -	A flat surface capable of being moved by the current of a fluid; as, for instance, the vanes of a windmill, moved by the wind.
Tappets - -	Projections on the plug-tree of a steam engine which open and shut the valves at proper intervals.
Varnish - -	A solution of certain resinous bodies in spirits or oils, which assumes a solid form on dissication.
Velocity - -	The measure of quickness with which a body moves.
Vertical - -	Perpendicular to the horizon.
Vibration - -	Rapid alternating motion.
Virtual head - -	The real or effective head.
Vis-inertia - -	*Vide* Inertia.
Wabble - -	A hobbling unequal motion.
Wallower - -	Small wheel with staff teeth; the trundle or lantern.
Warp - - -	The layer of threads which extends the length of the piece to be woven.
Washers - -	Small pieces of metal placed under a nut to reduce friction.

Water-wheel - -	A wheel which receives its impulse from water.
Weathering - -	The angle at which the sails of a windmill are set, to receive the impulse of the wind.
Wedge - - -	An angularly shaped piece of wood or metal; one of the mechanical powers.
Weft - - -	*Vide* Woof.
Weight - - -	The measure of the amount of the attraction of gravitation in any body compared with that of other bodies.
Welding - -	The property of conjunction possessed by some metals at high temperatures.
Wheel and Axis -	One of the mechanical powers.
Wheel-race - -	The place in which a water-wheel is fixed.
Whip - - -	To bind two rods together with small twine: the length of the sail of a windmill measured from the axis.
Whirl - - -	A rotatory motion with a decreasing speed.
Winch - - -	The lever or handle to which force is applied in machines turned by manual labour.
Wiper - - -	An eccentric.
Wire-draw - -	To reduce any longitudinal body exceedingly in the transverse section: rapid passage of a fluid through a conical orifice.
Woof - - -	Those portions of thread or yarn in cloth, which lie across the length of the warp.
Wrest or Wrist -	The partitions which determine the form of the bucket in an overshot wheel; the start or shoulder.
Yarn - - -	The combination of fibrous materials into a linear form by torsion.

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THE END.